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Scalar-isovector channel of the nucleon-nucleon interaction in the RMF theory and massive compact stars

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We discuss the role of scalar-isovector channel of nucleon-nucleon interaction in the framework of RMF theory to describe the equation of state of neutron star matter. It is shown that taking into account of this channel of interaction leads to a more stiff equation of state of hadronic component and, consequently, to an increase in the maximum mass of a compact star. Influence of scalar-isovector channel of interaction on the parameters of the quark-hadron phase transition is also studied. The integral parameters of the hybrid star are compared to each other with and without considering this type of interaction. The results obtained for the maximum mass of compact stars are compared to the values of the mass of recently observed massive neutron stars.

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Universal symmetry energy contribution to the neutron star equation of state

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We present systematic investigation of the Universal Symmetry Energy Con- jecture (USEC) starting from the observation made first in [1] that under con- ditions of charge neutrality and β−equilibrium the contribution from the asym- metry energy to the equation of state (EoS) for neutron star matter follows a universal behaviour unless the direct Urca (DU) process becomes allowed. It reveals that indeed the USEC holds provided the density dependence of the symmetry energy Es(n) follows a behaviour that limits the proton fraction x(n) to values below the DU threshold. The absence of DU cooling processes in typical mass neutron stars appears to be supported by the phenomenology of neutron star cooling data. Two classes of symmetry energy functions are investigated more in detail to elucidate the USEC. Both of them fulfill the constraint from a detailed analysis using isobaric analog states (IAS) [2] which revealed that E∗ = Es(n∗) = 26 MeV at a reference density n∗ = 0.106 fm−3. The first one follows an MDI type ansatz Es(n) = E∗ · (n/n∗)γ where the IAS constraint limits the admissible values of γ to the range 2/3 ≤ γ ≤ 9/10 when also the smaller variations at its lower limit for n = n0/4 are respected. With this ansatz the USEC is not directly apparent. The second one uses a recent parametrization of the density-dependent cou- plings in the isovector ρ meson channel within the generalized density functional approach to nuclear matter [3] leading to a moderate increase of the symmetry energy at supersaturation densities; gentle enough to fulfill the DU constraint in the whole range of densities relevant for neutron star interiors and thus in perfect agreement with the USEC. We discuss that this behaviour is shared with the APR EoS that respects the tensor force of the NN interaction. Note that recent work on short range correlations from the tensor force [4] suggests an MDI type parametrization with γ = 0.8. While this is apparently in line with the IAS constraint it would fulfill the USEC only for a sufficiently stiff symmetric part of the nuclear EoS.

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On the Kerr solution

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Calculations are carried out, on the base of which the limitations are revealed under which the general exact solution for the gravitational field, created by a uniformly rotating configuration, is reduced to the Kerr solution. It is found that in the derivation of the Kerr solution all the multipole moments are discarded and, in addition to the integration constant which define the mass of configuration, a parameter is introduced which is responsible for the rotation. Already in the first paper by Kerr, it was noted that the solution is an example of algebraically special metric of the same class as the known solution NUT. This allowed to reveal that the Kerr solution is a particular case of the known four-parameter solution which is obtained under the assumption of the potential nature of the angular velocity of the worldlines configuration, forming the used commoving coordinate system.

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A new RMF based quark-nuclear matter EoS

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The aim of our work is to develop a unified equation of state (EoS) for nuclear and quark matter for a wide range in temperature, density and isospin so that it becomes applicable for heavy ion collisions as well as for the astrophysics of neutron stars, their mergers and supernova explosions. As a first step we use improved EoS for the hadronic and quark matter phases (with particular focus on phase space occupation effects) and join them via Maxwell construction. This gives a solid fundament for further improvements which aim at a unified description of the phase transition on a more fundamental basis by a cluster virial expansion, which should then allow for predictions of the critical line in the three-dimensional QCD phase diagram.

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Magnetic field dependent neutron mass and equation of state

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Magnetars and pulsars are neutron stars with strong surface magnetic field which is about 1013 Gauss in case of pulsars [1] and 1015 Gauss in magnetars [2]. According to scalar virial theorem [3] the strength of magnetic field at the core of neutron stars exceed 1018 G. Such strong magnetic fields can change the internal structure of nucleons and reduce its mass [4]. Here, we have studied the influence of neutron mass reduction due to magnetic field on the equation of state of neutron matter. Here, we have used the lowest order constrained variational (LOCV) formalism and applied modern nucleon-nucleon potentials to determine the equation of state of the neutron matter. The LOCV method is a powerful tool for determination of the properties of the nucleonic matter [5].

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Towards a unified equation of state for quark/hadron matter

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The investigations exploring the phase boundary between hadronic matter and the quark-gluon plasma are in the dilemma that a proper theoretical basis is missing: a unified approach which can describe both phases on the same footing and deal properly with the transition between them. We suggest that a cluster virial expansion for quark-nuclear matter [1] formulated within the $\Phi-$derivable approach [2] to many particle systems with strong correlations can fill this gap. We define a generic form of $\Phi-$functionals that is fully equivalent to a selfconsistent cluster virial expansion up to the second virial coefficient for interactions among the clusters. As examples we consider nuclei in nuclear matter and hadrons in quark matter, with particular attention to the case of the deuterons in nuclear matter and mesons in quark matter. We derive a generalized Beth-Uhlenbeck equation of state for two-particle states in quark matter [3], and outline how the quasiparticle virial expansion is extended to include arbitrary clusters. The approach is applicable to nonrelativistic potential models of nuclear matter as well as to relativistic field theoretic generalizations of models for quark/nuclear matter like the string-flip model [4]. It is particularly suited for a description of cluster formation and dissociation in dense hadronic matter in compact star interiors and in heavy ion collisions such as planned for FAIR and NICA. [1] D. Blaschke, Cluster virial expansion for quark and nuclear matter, arxiv:1502.06279 [2] G. Baym, L.P. Kadanoff, Phys. Rev. 124, 287 (1961); G. Baym, Phys. Rev. 127, 1391 (1962). [3] D. Blaschke et al., Generalized Beth-Uhlenbeck approach Ann. Phys. 348, 228 (2014). [4] G. Roepke, D. Blaschke, H. Schulz, Pauli quenching effects in a simple string model of quark/nuclear matter, Phys. Rev. D 34, 3499 (1985).

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Structure of hybrid stars with the Field Correlator Method

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I will discuss the structure of hybrid stars built with equations of state (EoS) derived in the Field Correlator Method (FCM) for quark matter, and in the Bruckner-Hartree-Fock (BHF) theory for the hadronic matter, including hyperons. I will show that the FCM equation of state can be accurately represented by the “constant speed of sound” (CSS) parameterization, which assumes a sharp transition to a high-density phase with density-independent speed of sound. A mapping between the FCM and CSS parameters can be performed, according to the chosen values of the quark-antiquark potential V_1 and the gluon condensate G_2. The observation of a $2M_\odot$ neutron star mass allows FCM equations of state in a restricted subspace of the CSS parameters.

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Crystalline chiral condensates as a component of compact stars

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Could crystalline chiral condensates form in the core of compact stars? Can their existence be determined through astrophysical observations? In my talk, I will try to partially answer these questions. For this, I will first discuss the influence of some realistic astrophysical conditions on the mechanism of inhomogeneous chiral symmetry breaking and the structure of the energetically favored state of quark matter. I will then discuss possible observables related to the formation of crystalline condensates, with a particular emphasis on the effects on the equation of state of dense quark matter and its consequences on the resulting mass-radius sequences for compact stars.

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Constraint on the internal structure of neutron stars from pulsar glitches

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Pulsars are spinning extremely rapidly with periods ranging from milliseconds to seconds and delays of a few milliseconds per year at most, thus providing the most accurate clocks in the Universe. Nevertheless, sudden spin up have been detected in some pulsars like the emblematic Vela pulsar. These abrupt changes in the pulsar's rotation period have long been thought to be the manifestation of a neutron superfluid permeating the inner crust of neutron stars. However, the neutron superfluid has been recently found to be so strongly coupled to the crust that it does not carry enough angular momentum to explain the Vela data. We explore to which extent pulsar timing observations can be reconciled with the standard glitch theory considering the lack of knowledge of dense matter properties.

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Role of r-modes in evolution of recycled neutron stars

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Observations of hot rapidly rotating neutron stars in low-mass X-ray binaries (LMXBs) provide important constraints on the r-mode instability in neutron stars (see, e.g., Ref. [1]). Here we discuss additional constraints imposed on this instability, which follow from observations of recycled neutron stars. Recent Ref. [2] was devoted to the same subject and concluded that ''ungapped interacting quark matter is consistent with both the observed radio and x-ray data". However, this model leads to very high neutrino luminosity, thus high temperatures observed for neutron stars in LMXBs can hardly be explained (deep crustal heating is clearly not enough). We argue that *all* the models in which r-mode instability is suppressed by the bulk viscosity should face the same problem. Therefore we concentrate on our recent model [1] where r-mode instability is suppressed because of the resonant interaction of oscillation modes at some internal temperatures ("resonant temperatures"). Here we demonstrate that this model agrees with observations of millisecond pulsars and provide observational evidences that the coupling parameter for resonant mode interaction at low temperatures should be rather large, in agreement with theoretical expectations [1]. Furthermore, as shown in Ref. [3], in addition to millisecond pulsars, members of the new class of neutron stars – hot widows/HOFNARs – can be born in LMXBs. Recent observations confirm stability of the surface temperature of the quiescent neutron stars without power-law components [4]. This could indicate that some of those stars can, in fact, belong to hot widows/HOFNARs.
This study was partially supported by RFBR (grants 14-02-00868-a and 14-02- 31616-mol-a), and by RF president programme (grants MK-506.2014.2 and NSh-294.2014.2).
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Nuclear pairing from microscopic forces: singlet channels and higher-partial waves

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Pairing gaps [1] in isospin-symmetric nuclear matter and neutron matter are investigated using the chiral nucleon-nucleon potential at the N^3LO order in the two-body sector [2] and the N^2LO order in the three-body sector [2,3].
After a short introduction to chiral potentials and related techniques (renormalization group approaches [4]), we present results for the singlet channel ($^1S_0$) and higher partial coupled waves ($^3PF_2$ and $^3SD_1$) [5]. The role of three-body forces and other many-body correlations is discussed in comparison with available {\it ab-initio} microscopic calculations [1,6] whenever is possible.
We will also show **(a)** a preliminary analysis of the Cooper pair wavefunctions and **(b)** the extension of our formalism to finite temperature in connection with neutron star cooling mechanisms.
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Localized oscillating configurations formed by real scalar fields

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Self-gravitating real scalar fields can form extremely long living localized spherically symmetric oscillating objects, which are generally called oscillatons. These objects are very similar to boson stars, except that the geometry is not static, the metric components oscillate in time. In case of a zero cosmological constant oscillatons lose energy very slowly by scalar field radiation. However, in most cases this radiation is negligibly small, because the radiation amplitude decreases exponentially when the total mass of the oscillaton decreases. Since a negative cosmological constant acts as an effective attractive force, in that case exactly periodic non-radiating oscillatons exist, even for massless non-self interacting scalar fields. Numerical and analytical results will be presented about the one parameter family of oscillatons emerging from the nodeless linearized solution of the problem, both for the zero and negative cosmological constant cases. The stability range of these configurations was also investigated by applying a numerical time-evolution code.

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A self-consistent study of magnetic field effects on hybrid stars

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In this work we study the effects of strong magnetic fields on hy brid stars by using a full general-relativity approach, solving the coupled Maxwell-Einstei n equation in a self-consistent way. The magnetic field is assumed to be axi-symmetric and poloidal. W e take into consideration the anisotropy of the energy-momentum tensor due to the magneti c field, magnetic field effects on equation of state, the interaction between matter and the ma gnetic field (magnetization), and the anomalous magnetic moment of the hadrons. The equation of st ate used is an extended hadronic and quark SU(3) non-linear realization of the sigma model th at describes magnetized hybrid stars containing nucleons, hyperons and quarks. According to our results, the effects of the magnetization and the magnetic field on the EoS do not play an important role o n global properties of these stars. On the other hand, the magnetic field causes the central density in these objects to be reduced, inducing major changes in the populated degrees of freedom a nd, potentially, converting a hybrid star into a hadronic star.

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The quantum vacuum and the structure of empty space-time

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According to quantum field theory, the vacuum is a space all kinds of energetic particles and oscillating fields, which is in a state of statistical equilibrium is characterized by physical parameters and structure. Since the quantum vacuum pervades the entire extent of the universe then the study of its properties is a topical problem for deeply understanding of cosmology and in general for foundations of modern physics. Assuming that the quantum theory of field is possible precisely to describe without perturbation methods then the properties of the vacuum obviously will be analogous to the properties of an ensemble of the quantum harmonic oscillators. For the first time we considered this problem within limits of the stochastic differential equations of Maxwell–Langevin type. In particular assuming that fluctuations of the fields satisfy to properties of the "white noise" , we proved that the Casimir vacuum in an equilibrium is described by the 10-dimensional space-time, where $4D$ is the Minkowski space-time, while $6D$ is the compact topological space with the linear sizes of order 10^{-20} cm. It is shown that in the compact subspace is localized the main part of vacuum energy, which can claim the role of dark energy.

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Mass-radius relation of white and strange stars

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White dwarfs (WD) and strange dwarfs (SD) are considered. We investigate the mass-radius relations of these stars. Our investigations are carried out for various chemical compositions of the matter. It is believed that in both of WD and SD matters the mass number A of atomic nuclei is constant, and the atomic number Z is determined by the beta equilibrium. It is shown that the larger the collection of the values of A, the wider region of existence of SD on the mass-radius plane. Therefore, the number of candidates to SD among observed WD is greater than for A = 56. This fact renders WD and SD hardly distinguished.

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Compact stars with quark core

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For different hybrid models of neutron stars with deconfined quark phase in the core we investigate structural and observable characteristics to compare them with the measured data of massive pulsars. The observed constraints would allow learning an opportunity for testing equation of state for both the hadronic and quark matter phases.

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Inflationary evolution of the Universe within the framework of the modified JBD theory

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Certain conceptual difficulties arising in the construction of the cosmological evolution of the Universe (horizon and "flatness" problems), in fact, do not affect the Standard Model tested by known observations. They allow to determine reasonable initial conditions for classical Cosmology, the inflationary process, which transforms the exponential expansion near the Planck time to the power-law one.It is significant that while different areas of space, being on the "distance" H_0^{-1} (H_0 is the corresponding Hubble parameter) stop to interact, the "memory" on the previous connection remains that solves the horizon problem in the inflationary model. The "flatness" problem is solved in the case where during some time period the equation of state is given by $p = -\varepsilon$. In this case, during 70 Hubble times "flat" Universe is formed with accuracy 10^{-60}. Simultaneously the horizon problem is solved. This exotic equation of state occurs naturally in all sustainable models. In particular, the dynamics of a scalar field, under very natural assumptions, leads to a satisfactory inflationary expansion. In this work, within the framework of various conformal representations of the modified Jordan - Brans - Dicke theory, inflationary solutions are constructed by taking into account a specific scalar field for particular de Sitter models in which the Universe is filled by the vacuum. We consider the inflationary expansion from the Planck time till the beginning of the hot stage in the case of a minimally coupled scalar field. In the first model we take a massless scalar field and in the second one - a conformally coupled scalar field. In both cases there is a specific cosmological scalar that is an analogous of the variable cosmological constant.

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Softening of the Nuclear Matter and the Maximum Mass of the Neutron Star

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The equation of state (EOS) of the nuclear matter containing nucleons, leptons, and hyperons as relevant degrees of freedom is calculated in the framework of the free Fermi gas model at zero temperature. The system is supposed to be an uncharged mixture of mentioned particles which are in beta-equilibrium. The threshold density of each particle is determined in such matter. We find that the appearance of each new particle in the system results in softening the EOS. The equilibrium structure of the neutron star described by discussed EOS is also studied in the present article.

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Quantum effects in anti-de Sitter spacetime for electromagnetic vacuum state

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The two-point functions of the vector potential and of the field tensor for the electromagnetic field in background of anti-de Sitter (AdS) spacetime are evaluated. First we consider the two-point functions in the boundary-free geometry and then generalize the results in the presence of a reflecting boundary parallel to the AdS horizon. By using the expressions for the two-point functions of the field tensor, we investigate the vacuum expectation values of the electric field squared and of the energy-momentum tensor. Simple asymptotic expressions are provided near the AdS boundary and horizon.

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Late stage of the Universe evolution taking into account the vacuum effects

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The investigations of quantum vacuum effects indicate that in the phenomenology they are responsible for the existence of the cosmological constant Λ, and besides in the early de Sitter model one has $\Lambda \sim H^4$ (H- is the Hubble parameter), whereas for the vacuum energy induced by QCD condensate at late times $\Lambda \sim H$. In the present work, on the base of the modified Jordan theory, we consider models of the expanding Universe with a cosmological scalar $\varphi(y) = \alpha H^2$. For different values of the coupling constants ξ the values of the parameter α are obtained corresponding to an accelerated expansion.

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Purely phenomenological equation of state for nuclear matter

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The nuclear equation of state is still a very challenging issue for nuclear astrophysics, determining the masses and radii of neutron stars as well as the properties of core-collapse supernovae. Many nuclear modeling, being more or less phenomenological, exist but the relation between their parameters and the final astrophysical observation is usually quite complex and requires statistical analysis. In this talk, we will present a purely phenomenological equation of state which is able to mimic all existing modelings that we have tested. It stands for an unifying model for the nuclear equation of state, which main advantage is the clear relation between the empirical parameters of nuclear matter and the parameters of the model. We first apply this new approach to understand the relation between masses and radii of neutron stars and empirical parameters and identify the most determinant ones.

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From macro to micro: universal properties of neutron stars

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Universal I-Love-Q relations connect the moment of inertia, the tidal Love numbers and the quadrupole moment of a neutron star. Such identities are nearly independent from the star internal composition, and therefore they represent a valuable tool to test its features irrespective of the equation of state. In this talk will review the recent progress on the field. I will explore the domain of validity of I-Love-Q relations, and the attempts to provide a comprehensive description of their physical origin. Finally, I will show the prospect to use them with future gravitational and electromagnetic observations, to constraint the neutron star internal composition, and to derive information on its physical environment.

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Stiffening baryonic equation of state with hyperons

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Study of the structure and properties of neutron stars (NS) has attracted ever increasing theoretical and observational efforts during the last few decades [1]. The baryonic equation of state (EOS) is an essential step towards creating an efficient and convenient model for NS structure and composition [2-4]. Recent observations of two solar-mass NS, lead the EOS of theoretical models to a more stiff behavior until a value greater than of this value for the maximum mass of NS is obtained. Due to rapid increase of the nucleon chemical potential with density, hyperons are expected to appear. When strange matter is included in the structure, the EOS gets an inevitable soft behavior. Having large rest mass of hyperons, reduces of the kinetic energy density and lies these particles at lower momentum states. Therefore the EOS with hyperons needs to be stiffer. We can overcome to this softening mechanism through a generalized interaction to reach finally the value upper than $2M_\odot$ for maximum mass of NS. This generalized interaction of Myers and Swiatecki (MS) type [2,3] with explicit density and momentum dependent strength in phase space is:

$$V_{12} = -2\ G_{B1,B2}\ \rho_0^{-1} f(\frac{r_{12}}{a})\ \{\frac{1}{2}(1\mp\xi)\alpha - \frac{1}{2}(1\mp\zeta)\times[\beta(\frac{p_{12}}{p_b})^2 - \gamma(\frac{p_b}{|p_{12}|}) + \sigma(\frac{2\bar{\rho}}{\rho_0})^{\frac{2}{3}}]\} f(\frac{r_{12}}{a})$$

$$V_{12} = \frac{1}{4\pi a^3}\frac{exp(-\frac{r_{12}}{a})}{\frac{r_{12}}{a}}\bar{\rho}^{\frac{2}{3}} = \frac{1}{2}(\rho_1^{\frac{2}{3}} + \rho_2^{\frac{2}{3}}).$$

The interaction between like and unlike particles can be distinguished by *l,u* where the minus and plus signs indicate to like and unlike particles respectively:

$$\alpha_{l,u} = \frac{1}{2}(1\mp\xi)\alpha\ ,\ \beta_{l,u} = \frac{\eta}{2}(1\mp\zeta)\beta\ ,\ \gamma_{l,u} = \frac{1}{2}(1\mp\zeta)\gamma\ ,\ \sigma_{l,u} = \frac{\eta}{2}(1\mp\zeta)\sigma,$$

where $\eta = 1$ as that of MS potential for nucleon-nucleon interaction and $\eta = (\frac{\rho_B}{\rho_0})^{\frac{2}{3}}$ for hyperon-baryon interaction. According to the available hypernuclei experimental data, the Λ hyperon gets the best known adjustable potential well $U_\Lambda^{(N)} \simeq -30(MeV)$ in normal nuclear matter. In contrary to the $\Lambda - N$ interaction, we can't firmly extract the other potential well depths $U_i^{(j)}$ known as potential felt by baryon i-th in saturation density of baryonic matter j-th. This because, related hypernuclear experimental data are scared and ambiguous. Finally, we can generally adopt the following values $U_\Sigma^{(N)} \cong +30(MeV)$, $U_\Xi^{(N)} \cong -18(MeV)$ and:

$$U_\Xi^{(\Xi)} \cong U_\Sigma^{(\Xi)} \cong U_\Lambda^{(\Xi)} \cong U_\Sigma^{(\Sigma)} \cong U_\Xi^{(\Sigma)} \cong U_\Lambda^{(\Sigma)} \cong 2U_\Lambda^{(\Lambda)} \cong 2U_\Xi^{(\Lambda)} \cong 2U_\Sigma^{(\Lambda)} \cong -10(MeV).$$

As a result, the baryon-baryon coupling constants $G_{B1,B2}$ can be adjusted to the above constrain values for potential depths. Our main focus has been dedicated to study the possibility of how much the baryon-baryon interaction can affect to the stiffness of the EOS to

raise the maximum mass of NS in agreement with the resent observed mass. It was shown that the hyperon formation is very sensitive to the interactions furnished by the baryon-baryon coupling constants. Within our generalized interactions with hyperon degrees of freedom the maximum mass of NS is in the range $1.90 \sim 2.09 M_{\odot}$ for different interactions whereas within MS interactions this value is in the range $1.16 \sim 1.26 M_{\odot}$. Our findings about the stellar matter properties with strangeness content show the capability and the general applicability of our statistical model.

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A neutron star on a computer: recent developments

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Realistic global neutron star models require numerical approach. In this talk, I shall briefly motivate and recall the general-relativistic framework for the description of rotating compact stars and show how global observable quantities can be computed unambiguously. Then, I will present some recent results on the building of more detailed physical models, including realistic microphysics, following three directions. First, I shall describe the inclusion of magnetic field and its effects on both, global equilibrium and equation of state, second I will briefly sketch how one can use temperature-dependent approach in stationary models, and finally I will discuss superfluid (two-fluid) models in an attempt to model glitch phenomena.

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Inhomogeneous chiral symmetry breaking in isospin-asymmetric matter

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We investigate the phase structure of strong-interaction matter within a two-flavor Nambu–Jona-Lasinio model. For degenerate quark flavors it has already been shown that the appearance of chiral symmetry-breaking phases with spatially modulated order-parameters is possible. Since this might have significant consequences on the physics of compact stars, we analyze the emergence of these inhomogeneous phases in isospin asymmetric and charge neutral matter by allowing the order-parameter to be spatially modulated. We find that the formation of inhomogeneous chiral symmetry-breaking phases is still possible with an imbalance in the quark numbers. While enforcing equal quark periodicities, the appearance of such inhomogeneous phases is energetically disfavored in isospin asymmetric matter. However, by allowing unequal quark periodicities it is found that the inhomogeneous phase can be stabilized against the additional pairing stress.

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Wakefield generation by radiation beams of millisecond pulsars

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We study the generation of wake fields (WFs) by means of the high energy emission of pulsars. We examine a relatively simplified one dimensional model, considering the Euler equation, the continuity equation and the Poisson's equation in a two-component plasma. By linearizing the set of equations we estimate the potential difference created by the WFs and analyze the properties of this structure.

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Short-range correlations in nuclei and compact stars

Prof. PIASETZKY, Eliezer[1]

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Recent advances in the study of the short-range structure of nuclei indicate that about 25% of nucleons in medium to heavy nuclei have momentum greater than Fermi momentum (k > kF). These high-momentum nucleons are found to be predominantly short-range correlated proton-neutron pairs, created by the short-range tensor interaction. Since these high momentum nucleons significantly increase the average kinetic energy on nucleons in symmetric nuclear matter but not in pure-neutron matter, they should decrease the value of the kinetic part of the nuclear symmetry energy. In this talk I will review results from recent studies of correlations in nuclei and and their potential implications on astronomical object denser than nuclei.

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Atmospheres and radiating surfaces of neutron stars with strong magnetic fields

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Modern space telescopes have provided a wealth of valuable information on thermal radiation of neutron stars which, when properly interpreted, can elucidate the physics of superdense matter in the interior of these stars. Strong magnetic fields profoundly change the equation of state and radiative opacities in the surface layers of neutron stars and thus affect their thermal spectra. Theory of these effects is reviewed in the talk, including the conventional models of deep (semi-infinite) atmospheres, models of "naked" neutron stars with condensed radiative surfaces, and "thin" (finite) atmosphere models, with examples of application of the theory to tentative interpretations of some observed neutron-star thermal spectra.

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Unified treatment of sub-saturation stellar matter at zero and finite temperature

Author(s): RADUTA, Adriana[1]
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[1] *IFIN-HH*

[2] *LPC Caen*

The standard variational derivation of stellar matter structure in the Wigner-Seitz approximation is generalized to the finite temperature situation where a wide distribution of different

nuclear species can coexist in the same density and proton fraction condition, possibly out of β-equilibrium. The same theoretical formalism is shown to describe on one side the single-nucleus approximation (SNA), currently used in most core collapse supernova simulations, and on the other side the nuclear statistical equilibrium (NSE) approach, routinely employed in r- and p-process explosive nucleosynthesis problems. In particular we show that in-medium effects have to be accounted for in NSE to have a theoretical consistency between the zero and finite temperature modeling. The bulk part of these in-medium effects is analytically calculated and shown to be different from a van der Waals excluded volume term. This unified formalism allows controlling quantitatively the deviations from the SNA in the different thermodynamic conditions, as well as having a NSE model which is reliable at any arbitrarily low value of the temperature, with potential applications for neutron star cooling and accretion problems. We present different illustrative results with several mass models and effective interactions, showing the importance of accounting for the nuclear species distribution even at temperatures lower than 1 MeV.

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Vacuum currents in braneworlds

Author(s): Prof. SAHARIAN, Aram[1]
Co-author(s): Ms. SAHARYAN, Nvard [1] ; Mr. VARDANYAN, Valery [1]

[1] *Yerevan State University*

Vacuum expectation value (VEV) of the current density is investigated for a massive charged scalar field with arbitrary curvature coupling in the geometry of a brane on the background of AdS spacetime with partial toral compact dimensions. The presence of a gauge field flux, enclosed by compact dimensions, is assumed. On the brane the field obeys Robin boundary condition and along compact dimensions periodicity conditions with general phases are imposed. There is a range in the space of the values for the coefficient in the boundary condition where the Poincare vacuum is unstable. The vacuum charge density and the components of the current along non-compact dimensions vanish. The VEV of the current density along compact dimensions is a periodic function of the gauge field flux with the period equal to the flux quantum. It is decomposed into the boundary-free and brane-induced contributions. Both these contributions vanish on the AdS boundary. The brane-induced contribution vanishes on the horizon and for points near the horizon the current is dominated by the boundary-free part. Depending on the value of the Robin coefficient, the presence of the brane can either increase or decrease the vacuum currents. Applications are given for a higher-dimensional version of the Randall–Sundrum braneworld model.

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Electromagnetic Casimir densities for a cylindrical boundary in de Sitter spacetime

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Quantum vacuum effects are investigated for the electromagnetic field, induced by a conducting cylindrical shell in background of $(D+1)$ -dimensional de Sitter spacetime. We assum that the field is prepared in the Bunch-Davies vacuum state. A complete set of the electromagnetic field mode functions is determined. By using these mode functions, the vacuum expectation values (VEVs) of the electric field squared is evaluated for both exterior and interior regions. The VEVs are decomposed into the boundary-free and boundary-induced contributions. The behavior of the latter is investigated in various asymptotic regions of the parameters. For $D=3$ the boundary-induced VEV is related to the corresponding result for a cylindrical shell in Minkowski spacetime by standard conformal relation.

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Magnetic field of strange stars with rotating superfluid core

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The generation of a magnetic field and its distribution inside a rotating strange star are discussed. The difference between the angular velocities of the superfluid and superconducting quark core and of the normal electron plasma increases because of spin-down of the star and this leads to the generation of a magnetic field. The magnetic field distribution in a star is found for a stationary value of difference of angular velocities of these components. In all parts of the star this field is determined entirely by the total magnetic moment M of the star which can vary from 10ˆ31-10ˆ34 G·cmˆ3 for some models of compact stars.

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Extended time-dependent Ginzburg-Landau equations for rotating two-flavor color superconductors

Author(s): Prof. SHAHABASYAN, Karen[1]
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We discuss an extension of the time-dependent Ginzburg-Landau equations for rotating two-flavor color superconducting quark matter derived earlier. The extension treats the coefficient of the time-dependent term in the Ginzburg-Landau equation as complex number, whose imaginary part describes non-dissipative effects. We derive time- dependent London type equation for the color-electric potential which obtains an additional time-dependent contribution from this imaginary part. This additional term describes non-dissipative propagation effects. In addition we derive general expressions for the energy flux and the dissipative function of the system.

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Cosmology with nonminimal kinetic coupling and a Higgs potential

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In this work we continue an investigation of cosmological scenarios in the theory of gravity with the scalar field possessing a non-minimal kinetic coupling to the curvature, $\kappa\, G_{\mu\nu}\phi^\mu\phi^\nu$, [1-4]. Earlier, it was shown that the kinetic coupling provides an essentially new inflationary mechanism. Namely, at early cosmological times the domination of coupling terms in the field equations guarantees the quasi-De Sitter behavior of the scale factor: $a(t) \propto e^{H_\kappa t}$ with $H_\kappa = 1/\sqrt{9\kappa}$. In Ref. [4] we have studied the role of a power-law potential in models with non-minimal kinetic coupling. Now, we consider cosmological dynamics in such the models with the Higgs-like potential $V(\phi) = (\lambda/4)(\phi^2 - \phi_0^2)^2$. Using the dynamical system method, we analyze all possible asymptotical regimes of the model under investigation. As the most important result, we have found that, if the nonminimal coupling parameter $\varkappa$ is large enough to satisfy $2\pi G\kappa\lambda\phi_0^4 > 1$, then the local maximum of the Higgs potential becomes a stable node, and in this case one gets a late-time quasi-De Sitter evolution of the Universe. The cosmological constant in this epoch is $\Lambda_\infty = 3H_\infty^2 = 2\pi\lambda\phi_0^4$, and the Higgs potential reaches

its local maximum $V(0) = \lambda\phi_0^4/4$. Additionally, using a numerical analysis, we construct exact solutions and find initial conditions leading to various cosmological scenarios.

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A new family of compact objects: Dark Compact Planets

Author(s): TOLOS, Laura[1]
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[1] *ICE, Barcelona*

[2] *Frankfurt University*

A new family of compact objects formed by dark matter admixed with neutron star matter and white dwarf material is investigated [1]. We consider non-self annihilating dark matter with an equation-of-state given by an interacting Fermi gas. We obtain new stable solutions, dark compact planets. For weakly interacting dark matter, the dark compact planets have Earth-like masses and radii from few Km to few hundred Km, whereas they have Jupiter-like masses and radii of few hundred Km for the strongly interacting dark matter case. The dark compact planets could be formed primordially and accrete white dwarf material afterwards. They could be observed as exoplanets with unusually small radii. Furthermore, we find that the recently observed 2 $M_\odot$ pulsars set limits on the amount of dark matter inside neutron stars which is, at most, $10^{-6} M_\odot$.
[1] Laura Tolos and Juergen Schaffner-Bielich, arXiv:1507.08197 [astro-ph.HE]

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Pulsars with more exactly measured masses as possible candidates of strange stars

Author(s): Prof. VARTANYAN, Yuri[1]
Co-author(s): Dr. GRIGORYAN, Alexander [1] ; SHAHINYAN, Hasmik [1]

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The strange quark matter (SQM) has been studied for which the bag model was used. For considered case, it is shown that neutron stars with small mass and configurations consisted of SQM form one family on the curve of dependence of equilibrium superdense star mass on central density of energy r_c. The groups of the values of constants for bag model were determined, which application results in maximal mass of equilibrium configurations M_{max}, that are bigger compared with the recently precisely determined mass of binary radio pulsar $PSR\ \ J0348 \div 0432$ equal to $2.01 M_\odot$. For each series with $M_{max} > 2.01 M_\odot$, for configurations with masses equal to M_{max}, and 2.01, 1.97 and 1.44 sun masses, which were determined from observations with high precision, the values of radius, entire number of baryons as well as red sift from the strange star surface depending on r_c were calculated. In this case it turns out that all three pulsars with more accurately measured masses may be possible candidates for strange stars.

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Piercing the Vainshtein screen: local constraints on modified gravity

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By using observations of the Hulse-Taylor pulsar we constrain the gravitational wave (GW) speed to the level of 10^{-2}. We apply this result to scalar-tensor theories that generalize Galileon 4 and 5 models, which display anomalous propagation speed and coupling to matter for GWs. We argue that this effect survives conventional screening due to the persistence of a scalar field gradient inside virialized overdensities, which effectively "pierce" the Vainshtein screening. In specific branches of solutions, our result allows to directly constrain the cosmological couplings in the effective field theory of dark energy formalism.

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Hyperons and Neutron Stars

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In this talk I briefly review some of the effects of hyperons on neutron and proto-neutron star properties. I revise the problem of the strong softening of the EoS, and the consequent reduction of the maximum mass, due to the presence of hyperons, a puzzle which has become more intriguing due the recent measurements of the unusually high masses of the millisecond pulsars PSR J1903+0327 (1.667+/.0.021Msun), PSR J1614-2230 (1.97+/-0.04Msun) and PSR J0348+0432 (2.01 +/- 0.04 Msun). I examine also the role of hyperons on the cooling properties of newly born neutron stars and on the so-called r-mode instability.

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Noether and Lie symmetries of the field equations and their invariant solutions in Hybrid Gravity

Mrs. WOJNAR, Aneta[1]

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Symmetries play an important role in physics and, in particular, the Noether symmetry theorem is a useful tool to select models motivated at a fundamental level. Moreover, the symmetries help to find exact solutions of equations derived from a Lagrangian. In this work, we consider the application of point symmetries in the recently proposed hybrid metric-Palatini gravitational theory in order to select the f(R) function and to find analytical solutions of the field equations and of the Wheeler-DeWitt equation in quantum cosmology.

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Plasma gravitational bremsstrahlung in ADD

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We have developed the theory of interaction of classical plasma with Kaluza-Klein gravitons in the ADD model of TeV-scale gravity. Plasma is described within the kinetic approach as the system of charged particles and the Maxwell field both confined on the brane. Interaction with multidimensional gravity living in the bulk with n compact extra dimensions is introduced within the Linearized theory. Our interest is in computing KK gravitons emission rates taking into account in a consistent way the plasma collective effects. Apart from bremsstrahlung (which turn out to be modified for certain frequencies by plasma effects) we have essentially found collective mechanisms of the KK gravitons production such as the coalescence of two Langmuir waves into graviton.

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