BOOK OF ABSTRACTS

Welcome to Compact Stars in the QCD Phase Diagram III

It is a pleasure to welcome participants to the CSQCDIII meeting in the gorgeous coastal city of Guarujá, Brazil.

As in the previous editions, the meeting will cover recent developments in the study of cold matter at supra-nuclear densities. The aim of the conference is to bring together scientists from QCD exploring the phases of Quark Matter and astrophysicists working on Compact Stars and related phenomena. The main topics are:

- From Neutron Stars to Quark Stars
- Quark Matter
- Quark Stars
- QCD Phase

We would like to thank Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Fundação de Amparo à Pesquisa de Estado de São Paulo and Conselho Nacional de Desenvolvimento Científico e Tecnológico. Without their valuable support, this conference would not be happening.

We wish you all a productive meeting and are sure to have a great environment for the exchange of views and ideas, consolidation of partnerships and the beginning of new collaborations.

L. Paulucci and J. E. Horvath

COMMITTEES

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GENERAL INFORMATION

Language

The official language of the event is English.

The official language in Brazil is Portuguese. Be prepared to deal with non-English speakers on buses, restaurants, etc. However, it is a common characteristic of Brazilians to try to help foreigners as much as possible.

Currency

The currency in Brazil is Real (R$). You can exchange US Dollars, Euros, Pounds (only those issued by the Bank of England) to Reais at most banks and Exchange offices, but less used currencies may be difficult to exchange . Foreign currencies are not commonly accepted on the commerce, but credit cards are widely used (mainly VISA and MasterCard)

Electric equipment

The voltage in Guarujá is 110 V. The power outlet standard in Brazil is in the middle of a transition, so, unfortunately, you will find mixed options. We recommend taking with you an international power plug adapter if available.

Smoking policy

It is not allowed to smoke in any public closed spaces in the state of Sao Paulo. It includes airports, malls, buses, restaurants, pubs... It also includes partially closed spaces, for example, if a place is only covered by a roof or tent.

Meals

Lunch will be served at the hotel. Coffee-breaks are scheduled to happen twice a day, at 10:40 and 16:30. Dinners will not be provided by the organization but there are many options available nearby. Water stations are available at the hotel.

PROCEEDINGS

The Proceedings of the Conference will be published in eConf (Electronic Conference Proceedings Archive). Instructions as well as a template can be found in the page of the Conference. The suggested page limits are: 40’ talk: 12 p, 20’ talk: 6 p and poster: 4 p. These limits are not strict. The deadline to submit the manuscript is **April 30, 2013**.

INFORMATION FOR PRESENTERS

Speaker instructions

Time for speakers is 35 minutes + 5 minutes for questions or 18 minutes + 2 minutes for questions. It is highly recommended that you give your presentation to one of the organizers at least 2 hours prior to your scheduled session. Please remember to bring video files as separate files if you intend to make use of this resource. Contact any member of the LOC if you need any assistance.

Poster presenters

The organization will provide the adequate material for fixing posters which will be displayed during coffee-breaks. Posters can already be mounted in Dec 11 and removed on Dec 15.

In the afternoon of the first day of the event (12 december) there is allocated for poster presenters to give a $\sim$ 2 min (up to 2 slides) introduction to their poster. The format should be PDF (preferred) or powerpoint and should be passed to the organizers by the end of the morning session on Dec 12. We will then concatenate all files into a single file for the presentation.

Please remember that your presentation is an introduction to your poster. Do not attempt to present the whole story of your poster. Please do not exceed the 2 minutes presentation time.

OPENING EVENT

We would like to invite all participants to attend the opening ceremony of the event, to be given by Prof. Jorge Horvath on Dec 11 at 19:00:

"Opening: past events and the future of CSQCD Workshop"

It will be followed by a small cocktail.

SCIENTIFIC PROGRAMME

Time	**Dec 12**	**Dec 13**	**Dec 14**	**Dec 15**
09:00 - 09:20	*Registration*	G. Lugones	Renxin Xu	A. Li
09:20 - 09:40	I. Bombaci			O. Lourenço
09:40 - 10:00		S. Schramm	J. Wambach	M. Malheiro
10:00 - 10:20	O. Benvenuto			
10:20 - 10:40		R. Negreiros	G. Contrera	H. Mosquera
10:40 - 11:10	*Coffee break*	*Coffee break*	*Coffee break*	*Coffee break*
11:10 - 11:30	R. Ouyed	F. Weber	V. de la Incera	R. Belvedere
11:30 - 11:50				S. M. Carvalho
11:50 - 12:10	J. E. Horvath	G. Colvero	C. Albertus Torres	L. J. R Lemos
12:10 - 12:30	M. Avellar	C. Vásquez	S. Stetina	*Closing - Horvath*
12:30 - 14:00	*Lunch*	*Lunch*	*Lunch*	*Lunch*
14:00 - 15:30	*Free Time*	*Free Time*	*Free Time*	-
15:30 - 15:50	A. Santos	*Free Time*	L. Paulucci	-
15:50 - 16:30	E. Ferrer	M. A. Perez-Garcia	N. Scoccola	-
16:30 - 17:00	*Coffee break*	*Coffee break*	*Coffee break*	-
17:00 - 17:40	*Poster announcements*	A. P. Martinez	D. Blaschke	- -
17:40 - 18:00	M. Dareh Moradi	F. Navarra	L. Lopes	-
Discussion Session				-

DECEMBER 12

09:20 - 10:00

To be announced

I. Bombaci [1,*]

[1] *Dipartamento di Fisica, Universitá di Pisa, Pisa, Italy*

[*] *corresponding author: ignazio.bombaci@df.unipi.it*

10:00 - 10:40

Signals of Quark Matter deconfinement in proto neutron star evolution

O. G. Benvenuto[1,*] and J. E. Horvath[2]

[1] *Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, La Plata, Argentina, Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata and Instituto de Astrofísica de La Plata (IALP), CCT-CONICET-UNLP. La Plata, Argentina*

[2] *Instituto de Astronomia, Geofísica e Ciencias Atmosféricas, Universidade de São Paulo (IAG-USP), São Paulo, Brazil*

[*] *corresponding author: obenvenu@fcaglp.unlp.edu.ar*

Up to now there has been much speculation about the best way for detecting the formation of quark matter inside the objects usually called “neutron stars”. For example, it has been proposed that it could be possible to distinguish strange stars from neutron star by studying the mass radius relation or the occurrence of a giant glitch at the moment of quark matter formation. In this talk we give reasons why we consider that the most promising way to detect quark matter deconfinement is by studying the neutrino emission of forthcoming nearby supernovae. We discuss the reasons for expecting the occurrence of a bimodal detection in which the first maximum should correspond to the gravitational collapse of an imploding presupernova followed by a second one due to quark matter formation. We present some preliminary calculations of the first seconds of the evolution of proto neutron stars including the mentioned effect. We also discuss the conditions necessary for detecting such neutrino emission at Super-Kamiokande.

11:10 - 11:50

The Quark-Nova: Simulations and Observational Signatures

R. Ouyed[1,*]

[1] *University of Calgary, Calgary, Canada*

[*] *corresponding author: rouyed@ucalgary.ca*

I will present the Burn-UD code (**http://www.quarknova.ucalgary.ca/software.html**) for simulating the hadronic-to-quark-matter transition and the implications to the Quark-Nova model. I will also present updates (since CSQCD II) on our effort in the search for the Quark-Nova.

11:50 - 12:10

Is there a crisis in neutron star physics?

J. E. Horvath[1,*]

[1] *Instituto de Astronomia, Geofísica e Ciências Atmosféricas - USP, São Paulo, Brazil*

[*] *corresponding author: foton@iag.usp.br*

We review the recent observations and theories suggesting a high mass scale ($M > 2M_{\odot}$) for millisecond pulsars in binary systems and consider the theoretical situation of the EOS within different approaches to explain the data.

12:10 - 12:30

Entropy, complexity and disequilibrium in compact stars

M. de Avellar[1,*] and J. E. Horvath[1]

[1] *Instituto de Astronomia, Geofísica e Ciências Atmosféricas - USP, São Paulo, Brazil*

[*] *corresponding author: marcavel@astro.iag.usp.br*

We used the statistical measurements of information entropy, disequilibrium and complexity to infer a hierarchy of equations of state for two types of compact stars from the broad class of neutron stars, namely, with hadronic composition and with strange quark composition. Our results show that, since order costs energy, Nature would favor the exotic strange stars even though the question of how to form the strange stars cannot be answered within this approach. Finally, we comment on our new developments where we discuss and compare with the case of global charge neutrality instead of local charge neutrality as is usually done (R. Souza, D. Manreza Parets, M. de Avellar and J.E. Horvath, in preparation).

15:30 - 15:50

Compact stars within a soft symmetry energy quark-meson-coupling model

P. K. Panda[1]; A. M. S. Santos[2,*]; D. P. Menezes[3] and C. Providência[4]

[1] *Department of Physics, C.V. Raman College of Engineering, Vidya Nagar, Bhubaneswar, India*

[2] *Universidade Federal de Santa Catarina, Campus Curitibanos, Curitibanos, SC, Brazil*

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[4] *Centro de Física Computacional, Departamento de Física, Universidade de Coimbra, Coimbra, Portugal*

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We investigate compact star properties within the quark-meson-coupling model with a soft symmetry energy density dependence at large densities. In particular, the hyperon content and the mass/radius curves for the families of stars obtained within the model are discussed. The hyperon-meson couplings are chosen according to experimental values of the hyperon nuclear matter potentials, and possible uncertainties are considered. It is shown that a softer symmetry energy gives rise to stars with less hyperons, smaller radii, and larger masses. Hyperon-meson couplings may also have a strong effect on the mass of a star.

15:50 - 16:30

BEC-BCS Crossover and the EoS of Strongly Interacting Systems

E. Ferrer[1,*]

[1] *The University of Texas at El Paso, El Paso, USA*

[*] *corresponding author: ejferrer@utep.edu*

I will analyze how dense quark matter crossovers from a BCS regime to a BEC one at sufficiently strong coupling. Considering the EoS of this strongly interacting system, I will show that to avoid the BEC system to collapse into a pressureless gas at zero temperature, a diquark-diquark repulsion has to be self-consistently taken into account. The existence of a diquark-diquark interaction strength beyond which the tendency to condense at zero temperature of the diquark gas is compensated by the repulsion between diquarks will be discussed. Possible implications of the diquark-diquark interaction for the astrophysics of compact stars will be presented. Also I will discuss the effect of a strong magnetic field in the BEC-BCS crossover.

17:00 - 17:40

Poster announcements

17:40 - 18:00

The Effects of temperature on maximum mass of hybrid stars

M. D. Moradi[1,*] and A. Mohammadnejad[1]

[1] *University of Tehran, Tehran, Iran*

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In this work, we study the effects of the temperature on the equations of state (EOS) inside the neutron stars, quark stars, and neutron stars with quark core. We also investigate the properties of hybrid stars formed by hadronic and quark matter in equilibrium described by appropriate EOS. These compact objects are a suitable nominate for testing the equation of state of baryonic and quark matter for both zero and finite temperature. We have calculated the equation of state of hadronic matter part of star using two models, first we use statistical Thomas-Fermi approach by employing Myers-Swiatecki density dependent potential and then we do the same thing in the framework of the relativistic nonlinear Walecka model (NLWM). We have used MIT bag model with both constant and density dependent bag parameter, $B(\rho)$, for quark phase. In addition, we have examined the hadron-quark phase transition in the interior of star in two cases, the Maxwell and Glendenning construction. Eventually, for good agreement with the available recent observation data, we have considered finite temperature case which is a very vital for obtaining the maximum mass of hybrid stars.

DECEMBER 13

09:00 - 09:40

Quark stars: formation mechanisms and observational signatures

G. Lugones[1,*]

[1] *Universidade Federal do ABC, Santo André, Brazil*

[*] *corresponding author: german.lugones@ufabc.edu.br*

We review the mechanisms through which quark matter phases could be formed inside compact stars and discuss the expected observable signatures within each scenario.

09:40 - 10:20

Modeling of Hybrid Stars in Quark-Hadron Approaches

S. Schramm[1,*]; R. Negreiros[2]; V. Dexheimer[3] and J. Steinheimer[4]

[1] *FIAS, Goethe University Frankfurt, Germany*

[2] *Federal Fluminense University, Rio de Janeiro, Brazil*

[3] *Kent State University, Ohio, USA*

[4] *Lawrence Berkeley National Laboratory, Berkeley, USA*

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The investigation of strong interaction physics at extreme values of temperature and/or density is of central interest in ultra-relativistic heavy-ion physics as well as in the study of compact stars. It is generally assumed that in current heavy-ion collisions, e.g. at LHC, one has transversed to a state of quarks and gluons in the central fireball. Whether the same is true in the case of neutron stars is less clear. Many models show a core of quark or mixed matter for heavy stars. Therefore, in order to connect the studies of heavy-ion collisions and neutron stars physics one has to introduce models of strong interactions with the correct asymptotic degrees of freedom, i.e. hadrons at low densities/temperatures and quarks and gluons at the other end of the thermodynamic parameters. Furthermore, in order to be able to investigate possible complex phase structures of the matter including crossovers and first order phase transitions one has to define a unified description of hadronic and quark degrees of freedom. In the talk we will introduce models of this type, including the parity partners of the baryon octet as additional degrees of freedom, and discuss the general phase structure of the approaches. To ensure validity of the models at low density we compare various observables with results from lattice gauge calculations. We then investigate compact stars that contain a mixed phase of baryons and quarks. We determine the properties of the stars, considering rotation as well as strong magnetic fields. Introducing temperature effects we study the properties of proto-neutron stars and the cooling curves of the stars within the same framework.

10:20 - 10:40

Thermal Evolution of Rotating Neutron Stars

R. Negreiros[1,*]; S. Schramm[2] and F. Weber[3]

[1] *Federal Fluminense University, Rio de Janeiro, Brazil*

[2] *FIAS, Goethe University Frankfurt, Germany*

[3] *San Diego State University, San Diego, USA*

[*] *corresponding author: negreiros@if.uff.br*

There are many factors that contribute to the breaking of the spherical symmetry of a neutron star. Most notably is rotation, magnetic fields, and/or accretion of matter from companion stars. All these phenomena influence the macroscopic structures of neutron stars, and also impact their microscopic compositions. The purpose of this work is to investigate the cooling of rotationally deformed, two-dimensional (2D) neutron stars in the framework of general relativity theory, with the ultimate goal of better understand the impact of 2D effects on the thermal evolution of such objects. The cooling of neutron stars with different frequencies is computed self-consistently by combining a fully general relativistic 2D rotation code with a general relativistic 2D cooling code. We show that rotation can significantly influence the thermal evolution of rotating neutron stars. Among the major new aspects are the appearances of hot spots on the poles, and an increase of the thermal coupling times between the core and the crust of rotating neutron stars. We show that this increase is independent of the microscopic properties of the stellar core, but depends only on the frequency of the star.

11:10 - 11:50

Phase Transitions inside of Rotating Neutron Stars

F. Weber[1,*]; H. Rodrigues[1,2] and M. Orsaria[1,3]

[1] *San Diego State University, San Diego, USA*

[2] *Centro Federal de Educação Tecnológica do Rio de Janeiro, Rio de Janeiro, Brazil*

[3] *Universidad Nacional de La Plata, La Plata, Argentina*

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Isolated rotating neutron stars are gradually spinning down to lower frequencies because of the emission of magnetic dipole radiation and a wind of electron-positron pairs. This spin-down gradually compresses the matter inside of such neutron stars to higher and higher densities, leading to changes in the global properties and the hadronic core compositions of such objects. In particular, the spin-down may drive phase transitions in the cores of rotating neutron stars, as discussed in this talk. First, the structure and stability of rotating neutron stars will be discussed. This is followed by an overview of the different types of phase transitions that may be triggered by stellar spin-down. Finally, astrophysical signatures by means of which such phase transitions may register themselves observationally will be pointed out.

11:50 - 12:10

Evolution of proto-strange quark stars in the MIT bag model

G. Colvero[1,*] and G. Lugones[1]

[1] *Universidade Federal do ABC, Santo André, Brazil*

[*] *corresponding author: gustavocolvero@gmail.com*

We present the evolution of leptonized proto-strange stars. The luminosity curves associated with the energy of the escaping neutrinos and of pair annihilation near the star's surface are analysed. Stellar matter is described with the MIT bag model. We also consider modifications of the bag model incorporating extra phenomenological parameters inspired on QCD perturbative corrections.

12:10 - 12:30

Non radial oscillations of color superconducting self-bound stars

C. Vásquez Flores[1,*] and G. Lugones[1]

[1] *Universidade Federal do ABC, Santo André, Brazil*

[*] *corresponding author: cesarovfsky@gmail.com*

We investigate the effect of color superconductivity on the non-radial oscillations of pure self-bound quark stars using an equation of state in the framework of the MIT Bag model. The equations of non-radial oscillations are integrated within the Cowling approximation in order to determine the frequency of the fundamental mode and of the first and second pressure modes. We employ several parametrizations of the equation of state that result in a maximum mass larger than the mass of the recently observed pulsar PSR J1614-2230 with $M \sim 2M_{\odot}$. The pulsation frequencies are compared with the corresponding modes of hadron stars and quark stars without pairing. The here obtained results can be used to extract details about the internal composition of compact stars from observed modes of pulsation.

15:50 - 16:30

Deconfinement of quark content in neutron stars due to cosmic external agents

M. A. Perez-Garcia[1,*] and C. Albertus[1]

[1] *Instituto Universitario de Física Fundamental y Matemáticas de la Universidad de Salamanca (IUFFyM), Salamanca, Spain*

[*] *corresponding author: mperezga@usal.es*

In this contribution we will explain how self-annihilating dark matter may play a fundamental role in the nuclear-quark matter phase transition in the inside of dense cores in neutron stars. This mechanism may help in the deconfinement of the quark content of hadrons present in a cold degenerate environment if dark matter particle candidate masses are above 1 GeV. Current indications from direct and indirect detection experiments seem to converge to this mass spectrum range.

17:00 - 17:40

Anomalous-Magnetic-Moment Effects in the EoS of a Strongly Magnetized Dense Medium

E. Ferrer[1]; V. de la Incera[1]; D. Manreza Paret[2] and A. Pérez Martínez[3,*]

[1] *The University of Texas at El Paso, El Paso, USA*

[2] *Departamento de Física General, Facultad de Física, Universidad de la Habana, La Habana, Cuba*

[3] *Instituto de Cibernética, Matemática y Física (ICIMAF), La Habana, Cuba*

[*] *corresponding author: aurora@icimaf.cu*

We investigate the effects of the anomalous magnetic moment (AMM) in the EoS of a dense fermion system under a strong magnetic field. For the calculations of the energy and pressures we start from an effective Lagrangian that contains the anomalous magnetic moment found from the one-loop fermion self-energy taken in the strong-field limit. The approach used in our calculations avoids the appearance of some reported unphysical instabilities in the system that occur when the Schwinger value of the AMM is used instead. The Schwinger value of the AMM, which is linear in the magnetic field, is the leading term at weak field. Using it in the strong-field regime is inconsistent and can lead to unphysical results. Possible astrophysical implications of the obtained results will be discussed.

17:40 - 18:00

Strongly coupled quark gluon plasma in a magnetic field

D. A. Fogaca[1]; B. Frazon[1] and F. Navarra[1,*]

[1] *Instituto de Física, Universidade Federal de São Paulo, São Paulo, Brazil*

[*] *corresponding author: navarra@if.usp.br*

We have recently developed an equation of state for the cold and strongly coupled quark gluon plasma. (see Phys. Lett. B 700, 236 (2011)). With this EOS we were able to solve the TOV equations and find stable quark stars heavier than two solar masses (see arXiv:1203.6090 [astro-ph.SR]). In the present contribution we include the effects of a strong magnetic field.

DECEMBER 14

09:00 - 09:40

Compressed baryonic matter of astrophysics

Renxin Xu[1,*]

[1] *School of physics, Peking University, Beijing, China*

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Nuclei contain almost all the mass of normal baryonic matter. What if matter is compressed more and more? Where can we find such kind of matter? Why should one be interested in it? What could be its state? This is essentially a question of the fundamental strong interaction between quarks at low-energy scale and hence of the non-perturbative quantum chromo-dynamics, the solution of which would certainly be meaningful for us to understand one of the seven millennium prize problems (i.e., "Yang-Mills Theory"). Our answers are: compressed baryonic matter could be created during supernovae and it would be composed by quark-clusters the interaction between which might be Lennard-Jones-like.

09:40 - 10:20

Dipole polarizability of lead and the neutron star equation of state

J. Wambach[1,*]

[1] *Technical University Darmstadt, Darmstadt, Alemanha*

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I discuss a recent measurement of the complete dipole response of led 208 and constarints it provides on the neutron star equation of state.

10:20 - 10:40

Lattice QCD constrained non-local PNJL models in compact stars

G. A. Contrera[1,*]; D. Blaschke[2] and A. G. Grunfeld[3,4]

[1] *Gravitation, Astrophysics and Cosmology Group, FCAyG, UNLP, La Plata, Argentina*

[2] *Institute for Theoretical Physics, University of Wroclaw, Wroclaw, Poland*

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Nonlocal PNJL models allow for a detailed description of chiral quark dynamics with running quark masses and wave function renormalization in accordance with lattice QCD (LQCD) in vacuum. Their generalization to finite temperature T and chemical potential (μ) allows to reproduce the μ-dependence of the pseudocritical temperature from LQCD when a nonvanishing vector meson coupling is adjusted [1]. This restricts the region for the critical endpoint in the QCD phase diagram and stiffens the quark matter equation of state (EoS). It is demonstrated that the construction of a hybrid EoS for compact star applications within a two-phase approach employing the nonlocal PNJL EoS and an advanced hadronic EoS leads to the masquerade problem [2]. As a possible solution the construction of a unified quark-hadron matter description is outlined which follows from a beyond meanfield treatment of the model [3] within a generalized Beth-Uhlenbeck approach [4].

[1] G. A. Contrera, A. G. Grunfeld, D. B. Blaschke, arXiv:1207.4890

[2] M. Alford, M. Braby, M. Paris, S. Reddy, Astrophys. J. 629 (2005) 969

[3] A.E. Radzhabov, D. Blaschke, M. Buballa, M.K. Volkov, Phys. Rev. D83 (2011) 116004

[4] D. Zablocki, D. Blaschke, M. Buballa, in preparation

11:10 - 11:50

Electric Responses of Strongly Magnetized Fermion Systems

V. de la Incera [1,*]

[1] *The University of Texas at El Paso, El Paso, USA*

[*] *corresponding author: vincera@utep.edu*

In this talk I will discuss the effects of a strong magnetic field on the electric responses of relativistic fermion systems. The field influence on the electric susceptibilities of dense quark matter and QED will be presented and compared. The recently found effects of magnetoelectricity of color superconductivity and paraelectricity of QED will be discussed. Possible implications for compact star physics will be outlined.

11:50 - 12:10

What does the Lambda-Lambda interaction predict for double lambda hypernuclei?

C. Albertus[1,*]

[1] *Instituto Universitario de Física Fundamental y Matemáticas de la Universidad de Salamanca (IUFFyM), Salamanca, Spain*

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Data on LambdaLambda hypernuclei provide a unique method to learn details about the strangeness $S = -2$ sector of the baryon-baryon interaction. From the free space Bonn-Jülich potentials, determined from data on baryon-baryon scattering in the $S = 0, -1$ channels, we construct an interaction in the $S = -2$ sector to describe the experimentally known LL hypernuclei. After including short-range (Jastrow) and RPA correlations, we find masses for these LL hypernuclei in a reasonable agreement with data, taking into account theoretical and experimental uncertainties. Thus, we provide a natural extension, at low energies, of the Bonn-Jülich one-boson exchange potentials to the $S = -2$ channel.

12:10 - 12:30

From field theory to superfluid hydrodynamics of dense quark matter

M. Alford[1]; S.K. Mallavarapu; A. Schmitt[2] and S. Stetina[2,*]

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[2] *Institut fur Theoretische Physik, Technische Universitat Wien, Vienna, Austria*

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Hydrodynamics of superfluids can be described by formally dividing the fluid into a normal fluid and a superfluid part. In dense quark matter, at least one superfluid component is present due to conservation of baryon number and an additional one due to conservation of strangeness arises once one takes into account kaon condensation. We show, how such a two-component description emerges from an underlying scalar field theory which can be viewed as an effective theory for Kaons. Further more, we relate the occuring hydrodynamic quantites in the low-temperature limit to the microscopic parameters provided by the Lagrangian. We thereby close the gap between field theory and hydrodynamics, which are important for astrophysical calculations.

15:30 - 15:50

Superconducting phases of strange quark matter in the NJL model

L. Paulucci[1,*]; E. Ferrer[2]; V. de la Incera[2] and J. E. Horvath[3]

[1] *Universidade Federal do ABC (UFABC), Santo André, Brazil*

[2] *The University of Texas at El Paso (UTEP), El Paso, USA*

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We analyze the color-flavor-locked phase of strange quark matter modeled by the three-flavor Nambu-Jona-Lasinio (NJL) framework with and without magnetic field and discuss some additional constraints on the stability scenario when a high magnetic field is applied. We also present results of the 2SC phase within this framework (not magnetic). We compare the results obtained by employing the MIT Bag Model and discuss the pairing gap behavior and its influence on the equation of state.

15:50 - 16:30

Phase diagram of strongly interacting matter under strong magnetic fields

P. Allen[1] and N. N. Scoccola[1,*]

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Different aspects of the effect of strong magnetic fields on the quark matter phase diagram are analyzed using effective quiral quark models which include confinement effects through the coupling to the Polakov loop.

17:00 - 17:40

Thermodynamic instabilities in dynamical quark models with complex conjugate mass poles

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We show that the CJT thermodynamic potential of dynamical quark models with a quark propagator represented by complex conjugate mass poles inevitably exhibits thermodynamic instabilities. We find that the minimal coupling of the quark sector to a Polyakov loop potential can strongly suppress but not completely remove such instabilities. This general effect is explicitly demonstrated in the framework of a covariant, chirally symmetric, effective quark model.

17:40 - 18:00

The Influence of Hyperons and Strong Magnetic Field in Neutron Star Properties

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Neutron stars are among the most exotic objects in the universe and constitute a unique laboratory to study nuclear matter above the nuclear saturation density. In this work, we study the equation of state (EoS) of the nuclear matter within a relativistic model subject to a strong magnetic field. We then apply this EoS to study and describe some of the physical characteristics of neutron stars, especially the mass–radius relation and chemical compositions. To study the influence of the magnetic field and the hyperons in the stellar interior, we consider altogether four solutions: two different magnetic fields to obtain a weak and a strong influence; and two configurations: a family of neutron stars formed only by protons, electrons, and neutrons and a family formed by protons, electrons, neutrons, muons, and hyperons. The limit and the validity of the results found are discussed with some care. In all cases, the particles that constitute the neutron star are in β equilibrium and zero total net charge. Our work indicates that the effect of a strong magnetic field has to be taken into account in the description of magnetars, mainly if we believe that there are hyperons in their interior, in which case the influence of the magnetic field can increase the mass by more than 10 %. We have also seen that although a magnetar can reach $2.48\,M_\odot$, a natural explanation of why we do not know pulsars with masses above $2.0M_\odot$ arises. We also discuss how the magnetic field affects the strangeness fraction in some standard neutron star masses, and to conclude our paper, we revisit the direct Urca process related to the cooling of the neutron stars and show how it is affected by the hyperons and the magnetic field.

DECEMBER 15

09:00 - 09:20

Too massive neutron stars: The role of dark matter?

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The maximum mass of a neutron star is generally determined by the equation of state of the star material. In this study, we take into account dark matter particles, assumed to behave like fermions with a free parameter to account for the interaction strength among the particles, as a possible constituent of neutron stars. We find dark matter inside the star would soften the equation of state more strongly than that of hyperons, and reduce largely the maximum mass of the star. However, the neutron star maximum mass is sensitive to the particle mass of dark matter, and a very high neutron star mass larger than 2 solar mass could be achieved when the particle mass is small enough. Such kind of dark-matter-admixed neutron stars could explain the recent measurement of the Shapiro delay in the radio pulsar PSR J1614-2230, which yielded a neutron star mass of 2 solar mass that may be hardly reached when hyperons are considered only, as in the case of the microscopic Brueckner theory. Furthermore, in this particular case, we point out that the dark matter around a neutron star should also contribute to the mass measurement due to its pure gravitational effect. However, our numerically calculation illustrates that such contribution could be safely ignored because of the usual diluted dark matter environment assumed. We conclude that a very high mass measurement of about 2 solar mass requires a really stiff equation of state in neutron stars, and find a strong upper limit ($\leq 0.64GeV$) for the particle mass of non-self-annihilating dark matter based on the present model.

09:20 - 09:40

Hadron-quark phase transition through PNJL and hadronic models.

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In this talk we show some results regarding the hadron-quark phase transition using the approach of two different equations of state (EOS). We present the phase diagram in the temperature versus chemical potential plane, using the PNJL model in the description of the quark phase and the relativistic mean-field (RMF) nonlinear Walecka model for the hadronic phase. The physical consequences of using such a method are discussed. We show how that the short-range repulsion of the nuclear force changes the phase diagram in comparison with that constructed only via PNJL model. We also discuss how to use the two EOS approach in order to estimate the strength of the vector interaction in PNJL models.

09:40 - 10:20

Magnetic moments of SGRs and AXPs as white dwarfs pulsars

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The Anomalous X-ray Pulsars (AXPs) and Soft Gamma-ray Repeaters (SGRs) are some of the most interesting groups of pulsars that have been intensively studied in the recent years. They are seen usually as neutron stars with super strong magnetic elds B > 10^{14} G. However, in the last two years two SGRs with low magnetic elds B $\sim (10^{12-13})$ G have been detected. Moreover, fast and very magnetic WD pulsars have also been observed in the last years. Based on these new pulsar discoveries, white dwarf pulsars have been proposed as an alternative explanation to the observational features of SGRs and AXPs [1]. We discuss here the pulsar magnetic dipole moment m of SGRs and AXPs when a model based on a massive fast rotating highly magnetized white dwarf is considered. We show that the values for m obtained for almost all SGRs and AXPs are in agreement with the observed range $10^{34}\,emu \leq m \leq 10^{36}\,emu$ of isolated and polar magnetic white dwarfs. This supports the understanding of SGRs and AXPs as belonging to a class of very fast and magnetic massive white dwarfs, perfect in line with the recent astronomical observations of fast white dwarf pulsars.

[1] M. Malheiro, J. A. Rieda, and R. Ruffini, Publications of the Astronomical Society of Japan, Vol.64, No.3, 56 (2012)

10:20 - 10:40

Maximal electrically charged strange quark stars in nonlinear electrodynamics

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Ultra strong electric(magnetic) fields can appear on the surface of the so called strange quark stars (Sq-Ss) provided they be electrically charged. The matter making up these stars is envisaged as of equal number of unconfined quarks with flavor up, down and strange (u, d, s). According to the Bodmer-Witten conjecture, quark matter is expected to exist in the interior of either neutron stars or in the hypothetical strange stars. In the MIT bag model, quarks are treated as a degenerate Fermi gas confined to a region of space having a vacuum energy density B_{bag} (the Bag constant). Bare Sq-Ss and normal Sq-Ss (i.e., those possessing an electron-supported baryon crust) had been proposed as candidates to explain the properties of the puzzling X-ray source RX J1856.5-3754, canonical pulsars (PSR B1828-11, PSR B1642-03), anomalous X-ray pulsars and soft gamma-ray repeaters. Here we review the astrophysics of such hypothetical objects in the framework of nonlinear electrodynamics (NLED). It is shown that the dynamics expected in the MIT Bag Model is modified in virtue of the role played on the Sq-Ss hydrodynamical equilibrium (equation of state) by the ultra strong nonlinear electric field, which suggests the appearance of a structural instability stemming from the surplus pressure of ultra electrically charged stars. (A similar phenomenon having been shown to occur in super strongly magnetized neutron stars). Such instability may drive Sq-Ss either to collapse or to reversing the gravity direction producing big explosions which could explain the observational features of a class of gamma-ray bursts named short. Constraints on parameters entering the NLED theory are obtained.

11:10 - 11:30

Neutron star equilibrium configurations within a fully relativistic theory with strong, weak, electromagnetic and gravitational interactions

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11:30 - 11:50

On the Relativistic Feynman-Metropolis-Teller Equation of state at Finite Temperatures and low densities White Dwafs

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The Feynman-Metropolis-Teller (FMT) treatment considering a classic non-relativistic Thomas-Fermi model confined in a Wigner-Seitz cell has been recently generalized to relativistic regimes and applied to the description of non-rotating white-dwarfs in general relativity. We are extending the FMT treatment to the case of finite temperatures for white dwarfs with different nuclear compositions. Our aim is to understand the effects of finite temperatures on the structure of white dwarfs, constructing and analyzing their equation of state and mass-radius relation.

11:50 - 12:10

Luminosity Function of GRBs

L. J. R. Lemos[1,*]; M. Malheiro[1]; R. Ruffini[2] and C. L. Bianco[2]

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The luminosity function (LF) statistics applied to the BATSE GRBs (sources of GUSBAD catalog, Schmidt, 2004, ApJ, vol 616, pg 1072) is the theme approached in this work. The LF is a strong statistical tool to extract useful information from astrophysical samples, where the key point of this statistical analysis is in the detector sensitivity, where we have performed careful analysis. We applied the tool of the LF statistics to three GRB classes predicted by the Fireshell model (Ruffni et al., 2009 arXiv:0907.5517v1). One of the main differences between the Fireshell and Fireball models (Piran 2005, RvMP, vol 76, pg 1143 and Meszaros 2006, RPPh, vol 69, pg 2259) is the explanation of the GRB prompt emission, where the rst claims that it is divided in two physical processes: 1 - transparency of a optically thick reshell producing the P-GRB emission and 2 - interaction of a relativistic shell (composed by baryons $e\,e+\,\gamma$) against the CBM (circumburst medium), producing the emission so-called extended afterglow peak (EAP), Ruffni et al. (2009 arXiv:0907.5517v1). However, the Fireball model, the most quoted one, claims that the prompt emission is caused by interactions among several relativistic shells (composed by $e\,e+\,\gamma$) with different Lorentz γ-factors, a process called internal shocks. The transparency produces a strong short emission in the rst few seconds, called P-GRB. Thus, to the Fireshell model, the prompt emission is P-GRB + EAP. We produced, by LF statistics, predicted distributions of: peak $uxN(Fph\,pk)$, redshift $N(z)$ and peak luminosity $N(Lpk)$ for the three GRB classes predicted by Fireshell model; we also used three GRB rates. We looked for differences among the distributions, and in fact we found. We performed a comparison between the distributions predicted and observed (with and without redshifts), where we had to build a list with 220 GRBs with known redshifts. We also estimated the effects of the Malmquist bias in all samples, and we looked for a correlation between the isotropic luminosity and the Band peak spectral energy, Band et al. (1993, ApJ, vol 413, pg 281).

12:10 - 12:30

Review session - Jorge Horvath

POSTER SESSION ABSTRACTS

Chiral transition within effective quark models under magnetic fields

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We consider the simplest version of the Nambu–Jona-Lasinio (NJL) model in the Mean Field Approximation (MFA), in order to analyze hot and dense two flavor quark matter subject to strong magnetic fields. We pay especial attention to the case of a finite chemical potential, which has not yet been fully explored. Our results show that, for stronger fields, the first order segment of the transition line in the phase diagram increases with the magnetic strength while the coexistence chemical potential value, at low temperatures, decreases. In the present work, one of the most important results is related to the analysis of how these features affect the phase coexistence region in the $T - \rho_B$ plane. We find that the coexistence boundary oscillates around the $B = 0$ value for magnetic fields of the order $eB < 9.5m\pi^2$ which can be understood by investigating the filling of Landau levels at vanishing temperature. So far, most investigations have been concerned with the effects of the magnetic field over the $T - \mu$ plane only while other thermodynamical quantities such as the adiabats, the quark number susceptibility, the interaction measure and the latent heat have been neglected. Here, we take a step towards filling this gap by investigating the influence of a magnetic field over these quantities.

Hybrid Stars in the light of the massive pulsar PSR J16142230

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We perform a systematic study of hybrid star configurations using several parameterizations of a relativistic meanfield hadronic equation of state (EoS) and the Nambu–Jona–Lasinio (NJL) model for three-flavor quark matter. For the hadronic phase we use the stiff GM1 and TM1 parameterizations, as well as the very stiff NL3 model. In the NJL Lagrangian we include scalar, vector, and 't Hooft interactions. The vector coupling constant gv is treated as a free parameter. We also consider that there is a split between the deconfinement and the chiral phase transitions which is controlled by changing the conventional value of the vacuum pressure $-\Omega_0$ in the NJL thermodynamic potential by $-(\Omega_0 + \delta\Omega_0)$, with $\delta\Omega_0$ a free parameter. We find that, as we increase the value of $\delta\Omega_0$, hybrid stars have a larger maximum mass but are less stable, i.e., hybrid configurations are stable within a smaller range of central densities. For large enough $\delta\Omega_0$, stable hybrid configurations are not possible at all. The effect of increasing the coupling constant g_v is very similar. We show that stable hybrid configurations with a maximum mass larger than the observed mass of the pulsar PSR J1614-2230 are possible for a large region of the parameter space of gv and $\delta\Omega_0$ provided the hadronic EoS contains nucleons only. When the baryon octet is included in the hadronic phase, only a very small region of the parameter space allows an explanation of the mass of PSR J1614-2230. We compare our results

with previous calculations of hybrid stars within the NJL model. We show that it is possible to obtain stable hybrid configurations also in the case $\delta\Omega_0 = 0$ that corresponds to the conventional NJL model for which the pressure and density vanish at zero temperature and chemical potential.

Stability Windows for Proto-quark Stars

D. F. Tamayo[1,*]; J. R. Torres[1]; V. A. Dexheimer[1] and D. P. Menezes[1]

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We calculate stability windows at finite temperature for different models that are generally applied to describe quark stars, namely, the MIT bag model, the Quark Mass Density Dependent model and the Nambu-Jona-Lasinio model. We emphasize that the quantity that has to be used to define stable matter at finite temperature is the free energy and we check the stability window up to temperatures of the order of $40 MeV$. The effects of strong magnetic fields on the stability windows and resulting mass-radius relation are also computed and analysed.

Effects of a strong magnetic field on the composition of nuclear matter including the anomalous magnetic moment

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In this work we investigate the effects of a strong magnetic field on the composition of nuclear matter at high densities and zero temperature. We describe the matter through a relativistic mean field model with eight baryons (baryon octet), electrons and muons. The anomalous magnetic moments of baryons were included in our calculations. The populations of particles, energy density and pressure were obtained numerically by iteration. We compare the results with and without anomalous magnetic moment in the presence of a very intense magnetic field.

Similarities of SGRs with low magnetic field and white dwarf pulsars

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Some of the most interesting types of astrophysical objects that have been intensively studied in the recent years are the Anomalous X-ray Pulsars (AXPs) and Soft Gamma-ray Repeaters (SGRs) seen usually as neutron stars pulsars with super strong magnetic fields. However, in the last two years two SGRs with low magnetic fields have been detected. Moreover, fast and very magnetic white dwarf pulsars have also been observed in the last years. Based on these new pulsar discoveries, white dwarf pulsars have been proposed as an alternative explanation to the observational features of SGRs and AXPs. Here we present several properties of these SGRs/AXPs as WD pulsar, in particular the surface magnetic field and the magnetic dipole momentum.

Evolution of Proto-Neutron Stars and Nuclear Pasta

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A protoneutron star is believed to be born from the collapse of a very massive star and a supernova explosion. During the rst few seconds of the star evolution, almost all the binding energy is taken away by the neutrinos. The neutrino luminosity is controlled mainly by the total protoneutron star mass and the neutrino opacity. In this thesis we show that an important difference in the evolution of a protoneutron star is seen if a pasta phase is present in its inner crust. The deleptonization and cooling processes take longer than if the crust would be made of homogeneous matter only. This statement results from the smaller diffusion coefcients obtained with the inclusion of the pasta phase. The diffusion coefcients present in the transport equations determine the temporal behavior associated with the deleptonization and cooling processes. The nuclear pasta was calculated by the coexistence phases method. We have assumed total charge neutrality, b-equilibrium and neutrino trapping in the equation of state. The surface energy coefcient was obtained with three different parametrizations and one of them practically reproduces results obtained with the more sophisticated Thomas-Fermi method, yielding credibility to our method.

Description of light clusters in relativistic nuclear models

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The dissolution density of light clusters in uniform nuclear matter was studied within the framework of the non-linear Walecka model. The effect of the cluster- meson coupling constants on the dissolution density is discussed. Theoretical and experimental constraints are used to fix the cluster-meson couplings. The relative light cluster fractions are calculated for asymmetric matter in chemical equilibrium at finite temperature. It is found that above $T = 5MeV$ deuterons and tritons are the clusters in larger abundances. The results do not dependent strongly on the relativistic mean field interaction chosen.

Phase structure of hadronic and Polyakov-loop extended NJL model at finite isospin density

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It is believed that there exists a rich phase structure of quantum chromodynamics (QCD) at finite temperature and baryon density, namely, the deconfinement process from hadron gas to quark–gluon plasma, the transition from chiral symmetry breaking phase to the symmetry restoration phase, and the color superconductivity at low temperature and high baryon density. In the present work we study the hadron-quark phase transition by investigating the binodal surface and extending it to finite temperature in order to mimic the QCD phase diagram. In order to obtain these conditions we use different models for the two possible phases, namely the quark and hadron phases. The phase separation boundary (binodal) is determined by the Gibbs criteria for phase equilibrium. The boundaries of the mixed phase and the related critical points for symmetric and asymmetric matter are obtained. Isospin effects appear to be rather significant. The critical endpoint (CEP) and the phase structure are studied in the Polyakov-loop extended Nambu–Jona-Lasinio model.

Statistical measure of complexity in compact stars with global charge neutrality

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Recently, it has been suggested that a critical electrical field arises during the gravitational collapse of massive stars leading to a vacuum polarization. This, in turn, leads to the necessity of a reexamination of the gravito-electrodynamical properties of compact stars of the class of neutron stars. Rotondo, Rueda, Ruffini and Xue claim to have proved the impossibility of local charge neutrality and then solved the coupled system of the general relativistic Thomas-Fermi-Einstein-Maxwell equations for the structure of neutron stars. Within the same approach of Avellar and Horvath (2012) we have calculated how the global neutrality hypothesis affects the order/disorder of these systems for a simple equation of state. We show the relative preference of local vs. global conservation in terms of the obtained information content of the systems under consideration.

Vector-like Contributions in the NJL model for Magnetized Quark Matter

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The main aspects of the inclusion of a vector coupling channel to the stan- dard Nambu–Jona-Lasinio model are discussed when quark matter is subject to external magnetic fields. At finite temperatures and nonzero chemical po- tential we observe the Inverse Magnetic Catalysis [1, 2] which decreases the coexistence chemical potential and expands the first order region in the QCD phase diagram. The consideration of a repulsive vector interaction induces an opposite effect by shrinking the first order transition line and setting the coexistence chemical potential to higher values. In this way, the chiral tran- sition can take place at density values which are more closely related to the case where the magnetic field is absent. Since the upper Landau level de- pends strictly on the Fermi surface and effective chemical potential, the De Haas-van Alphen oscillations are suppressed at high values of magnetic field when a vector coupling is taken into account. Extreme magnetic field values are expected to occur in non central heavy ion collisions, magnetar cores or even in the primordial universe. In this work, we discuss the effects of a magnetic field in the QCD phase diagram in the presence of a repulsive vector channel.

[1] F. Preis, A. Rebhan and A. Schmitt, arxiv:1209.4468 [hep-ph].

[2] V.P. Gusynin, V.A. Miransky and I.A. Shovkovy , Phys. Rev. Lett. 73,3499 (1944).

Hyperon stars under strong magnetic fields

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We investigate the effect of strong magnetic fields on the properties of a neutron star that contains hyperons on its constitution. The hadronic phase is described by an extension of ZM Model in which the coupling of hadrons and mesons is adjustable by means of a parameter λ that will be related to the effective mass of nucleon. The presence of strong magnetic fields affects the equation of state (EoS) of the matter by Landau quantization. Two parametrisations of a density dependent static magnetic field are considered, reaching $2 - 4 \times 10^{18}\,G$ in the center of the star. Finally, the Tolman-Oppenheimer-Volkov (TOV) equations are solved, showing the effects of including strong magnetic fields and different hyperonic coupling schemes on mass-radius relation and population of hyperon stars.

Gravitational wave generation in rotating protoneutron star

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Pulsars instabilities have been investigated as an important source of gravitational wave generation in astrophysical sites. The formation of this object is accompanied by a very intense neutrino flux emission, which cools down the nascent protoneutron star and leads to a contraction of the rotating pulsar structure. This work describes the evolution in time of this phase using an ellipsoidal shape parameterization for the pulsar surface and employing an effective lagrangian approach to discuss the problem. The effect of neutrino escape on the gravitational wave generation is determined. The time evolution of the gravitational wave luminosity, as well as the angular moment of the pulsar and its shape evolution are also calculated.

Quark deconfinement in protoneutron star cores: Analysis within the MIT Bag model

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We analyze the effect of color superconductivity in the transition from hot hadron matter to quark matter in the presence of a gas of trapped electron neutrinos. To describe strongly interacting matter we adopt a two-phase picture in which the hadronic phase is described trough a non-linear Walecka model and just deconfined matter through the MIT bag model including color superconductivity. We impose flavor conservation during the transition in such a way that just deconfined quark matter is transitorily out of equilibrium with respect to weak interactions. Our results show that color superconductivity facilitates the transition for temperatures below Tc. This effect may be strong if the superconducting gap is large enough. As in previous work we find that trapped neutrinos increase the critical density for deconfinement; however, if the just deconfined phase is color superconducting this effect is weaker than if deconfined matter is unpaired. We compare our results with those previously obtained employing the Nambu-Jona-Lasinio model in the description of just deconfined matter and show that they are in excellent agreement if the bag constant B is properly chosen. When color superconductivity is taken into account, both cooling and deleptonization of the protoneutron star tend to increase the probability of deconfinement as the protoneutron star evolves.