Selected Abstracts from Other Physical Review Journals

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Bremsstrahlung photons from the bare surface of a strange quark star. Prashanth Jaikumar,[1] Charles Gale,[1] Dany Page,[2] and Madappa Prakash[3] [1]*Physics Department, McGill University, Montréal, Québec, Canada H3A 2T8,* [2]*Instituto di Astronomia, UNAM, Mexico D.F. 04510, Mexico,* [3]*Department of Physics & Astronomy, SUNY at Stony Brook, Stony Brook, New York 11794, USA.* (Received 17 March 2004; published 23 July 2004)

The photon emissivity from the bremsstrahlung process $e^-e^- \rightarrow e^-e^-\gamma$ occurring in the electrosphere at the bare surface of a strange quark star is calculated. For surface temperatures $T < 10^9$ K, the photon flux exceeds that of e^+e^- pairs that are produced via the Schwinger mechanism in the presence of a strong electric field that binds electrons to the surface of the quark star. The average energy of photons emitted from the bremsstrahlung process can be around 0.5 MeV, which is comparable to that in e^+e^- pair annihilation. The observation of this distinctive photon spectrum would constitute an unmistakable signature of a strange quark star and shed light on color superconductivity at stellar densities. [Phys. Rev. D **70**, 023004 (2004)]

Three-dimensional calculation of atmospheric neutrinos. G. D. Barr,[1] T. K. Gaisser,[2] P. Lipari,[3] S. Robbins,[1] and T. Stanev[2] [1]*Department of Physics, University of Oxford, Denys Wilkinson Building, Keble Road, Oxford 0X1 3RH, United Kingdom,* [2]*Bartol Research Institute, University of Delaware, Newark, Delaware 19716, USA,* [3]*Dipartmento di Fisica, Universitá di Roma (La Sapienza), and INFN, Sezione di Roma, P. A. Moro 2, I-00185 Roma, Italy.* (Received 30 March 2004; published 27 July 2004)

A Monte Carlo calculation of the atmospheric neutrino fluxes [Barr *et al.*, Phys. Rev. D **39**, 3532 (1989); Agrawal *et al.*, *ibid.* **53**, 1314 (1996)] has been extended to take account of the three-dimensional (3D) nature of the problem, including the bending of secondary particles in the geomagnetic field. Emphasis has been placed on minimizing the approximations when introducing the 3D considerations. In this paper, we describe the techniques used and quantify the effects of the small approximations which remain. We compare 3D and 1D calculations using the same physics input in order to evaluate the conditions under which the 3D calculation is required and when the considerably simpler 1D calculation is adequate. We find that the 1D and 3D results are essentially identical for $E_\nu > 5$ GeV except for small effects in the azimuthal distributions due to bending of the secondary muon by the geomagnetic field during their propagation in the atmosphere. [Phys. Rev. D **70**, 023006 (2004)]

Relic neutrino absorption spectroscopy. Birgit Eberle and Andreas Ringwald, *Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, D-22607 Hamburg, Germany;* Liguo Song, *Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235, USA;* Thomas J. Weiler, *Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee 37235, USA, and Kavli Institute for Particle Astrophysics and Cosmology, Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, California 94025, USA.* (Received 27 January 2004; published 28 July 2004)

Resonant annihilation of extremely high-energy cosmic neutrinos on big-bang relic anti-neutrinos (and vice versa) into Z bosons leads to sizable absorption dips in the neutrino flux to be observed at Earth. The high-energy edges of these dips are fixed, via the resonance energies, by the neutrino masses alone. Their depths are determined by the cosmic neutrino background density, by the cosmological parameters determining the expansion rate of the Universe, and by the large redshift history of the cosmic neutrino sources. We investigate the possibility of determining the existence of the cosmic neutrino background within the next decade from a measurement of these absorption dips in the neutrino flux. As a by-product, we study the prospects to infer the absolute neutrino mass scale. We find that, with the presently planned neutrino detectors (ANITA, Auger, EUSO, OWL, RICE, and SalSA) operating in the relevant energy regime above 10^{21} eV, relic neutrino absorption spectroscopy becomes a realistic possibility. It requires, however, the existence of extremely powerful neutrino sources, which should be opaque to nucleons and high-energy photons to evade present constraints. Furthermore, the neutrino mass spectrum must be quasidegenerate to optimize the dip, which implies $m_\nu \gtrsim 0.1$ eV for the lightest neutrino. With a second generation of neutrino detectors, these demanding requirements can be relaxed considerably. [Phys. Rev. D **70**, 023007 (2004)]

Majorana neutrino masses, neutrinoless double beta decay, and nuclear matrix elements. S. M. Bilenky,[1]* Amand Faessler,[2] and F. Šimkovic[2†] [1]*SISSA, via Beirut 2-4, Trieste, 34014, Italy* [2]*Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany* (Received 21 February 2004; published 17 August 2004)

The effective Majorana neutrino mass $m_{\beta\beta}$ is evaluated by using the latest results of neutrino oscillation experiments. The problems of the neutrino mixing pattern, the absolute mass scale of neutrinos, and the effect of *CP* phases are addressed. A connection to the next generation of neutrinoless double beta decay ($0\nu\beta\beta$ decay) experiments is discussed. The calculations are performed for ^{76}Ge, ^{100}Mo, ^{136}Xe, and ^{130}Te by using the advantage of recently evaluated nuclear matrix elements with significantly reduced theoretical uncertainty. The importance of observation of the $0\nu\beta\beta$ decay of several nuclei is stressed. [Phys. Rev. D **70**, 033003 (2004)]

Appearance of neutronization peak and decaying supernova neutrinos. Shin'ichiro Ando, *Department of Physics, School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.* (Received 13 April 2004; published 17 August 2004)

Nonradiative neutrino decay, which is not satisfactorily constrained, possibly and significantly changes the detected neutrino signal from galactic supernova explosions. We focus on the appearance of a sharp peak due to a neutronization burst in the time profile; this phenomenon would occur if the original ν_e, produced at the neutrinosphere and becoming ν_2 or ν_3 at the stellar surface, decays into a lighter antineutrino state such as $\bar{\nu}_1$ or $\bar{\nu}_2$ coupled to $\bar{\nu}_e$. This is due to the fact that the signature of the neutronization burst is common to all numerical simulations, contrary to the spectral energy distribution of each flavor neutrino and antineutrino, which is still under intense debate. Therefore, the appearance of a neutronization peak in the $\bar{\nu}_e$ signal, if it were detected, would clearly indicate the nonstandard properties of neutrinos; the nonradiative neutrino decay would be one of the possible candidates. Using a newly developed formulation that includes flavor conversions inside the supernova envelope and neutrino decay during propagation in a vacuum, we calculate the expected neutrino signal at the detectors; the lifetimes of three modes τ_{12}, τ_{13}, and τ_{23} are taken to be free parameters. We further introduce simple quantities, which represent a peak sharpness of the time profile and spectral hardness, and investigate the parameter dependence of these quantities. As the result, it is found that they are quite dependent on the relevant parameters, but it would be quite difficult to distinguish models using the signal obtained by the Super-Kamiokande detector; the future megaton-class detectors would have sufficient sensitivity. We also compare the neutrino decay model with another mechanism—i.e., resonant spin-flavor conversion—which also may give the appearance of a neutronization peak, and conclude that these two independent mechanisms give a very different signal and one can be distinguished from the other. [Phys. Rev. D **70**, 033004 (2004)]

Magnetic moment of a massive neutrino due to its pion cloud. R. Tegen[1,2] and H. G. Miller[1] [1]*Department of Physics, University of Pretoria, Pretoria 0001, South Africa,* [2]*Institut für Theoretische Physik, JWG-Universität Frankfurt, Robert-Mayer-Strasse 8-10, D-60054 Frankfurt, Germany.* (Received 5 March 2004; published 17 August 2004)

In this work we have calculated the magnetic moment μ_ν of a massive neutrino, to one-pion loop order. If m_ν varies between ~ 3 meV and ~ 3 eV and m_π between 0 and ~ 140 MeV one obtains values for μ_ν which can compete with the Standard Model result in the chiral limit $m_\pi \to 0$. The photon coupling to the $\pi\pi$-intermediate state leads to the presence of ''chiral singularities'' [m_π^{-1}- and $\log(m_\pi)$-terms]. There are no such terms for the W^-W^+-intermediate state of the Standard Model. As a result μ_ν is particularly sensitive to the mass ratios $(m_\pi/m_\ell, m_{\nu_\ell}/m_\ell)$; this indicates to us that all electromagnetic properties of neutrinos $(\mu_\nu, \langle r^2 \rangle$, etc.) are expected to change significantly in a dense or hot medium. Such medium modifications of $\mu_\nu, \langle r^2 \rangle$, etc. are entirely due to the $\pi\pi$-intermediate state which acts as a ''doorway'' state for the photon-neutrino coupling. [Phys. Rev. D **70**, 033005 (2004)]

Atmospheric neutrino oscillations and new physics. M. C. Gonzalez-Garcia, *C.N. Yang Institute for Theoretical Physics, SUNY at Stony Brook, Stony Brook, New York 11794-3840, USA, and IFIC, Universitat de València - C.S.I.C., Apt 22085, E-46071 València, Spain;* Michele Maltoni, *C.N. Yang Institute for Theoretical Physics, SUNY at Stony Brook, Stony Brook, New York 11794-3840, USA.* (Received 19 April 2004; published 23 August 2004)

We study the robustness of the determination of the neutrino masses and mixing from the analysis of atmospheric and K2K data under the presence of different forms of phenomenologically allowed new physics in the $\nu_\mu - \nu_\tau$ sector. We focus on vector and tensor-like new physics interactions which allow us to treat, in a model independent way, effects due to the violation of the equivalence principle, violations of the Lorentz invariance both CPT conserving and CPT violating, non-universal couplings to a torsion field and non-standard neutrino interactions with matter. We perform a global analysis of the full atmospheric data from SKI together with long baseline K2K data in the presence of $\nu_\mu \to \nu_\tau$ transitions driven by neutrino masses and mixing together with subdominant effects due to these forms of new physics. We show that within the present degree of experimental precision, the extracted values of masses and mixing are robust under those effects and we derive the upper bounds on the possible strength of these new interactions in the $\nu_\mu - \nu_\tau$ sector. [Phys. Rev. D **70**, 033010 (2004)]

What can we learn from neutrinoless double beta decay experiments? John N. Bahcall, Hitoshi Murayama, and C. Peña-Garay, *School of Natural Sciences, Institute for Advanced Study, Princeton, New Jersey 08540, USA.* (Received 7 April 2004; published 26 August 2004)

We assess how well next-generation neutrinoless double beta decay and normal neutrino beta decay experiments can answer four fundamental questions. (1) If neutrinoless double beta decay searches do not detect a signal, and if the spectrum is known to be inverted hierarchy, can we conclude that neutrinos are Dirac particles? (2) If neutrinoless double beta decay searches are negative and a next-generation ordinary beta decay experiment detects the neutrino mass scale, can we conclude that neutrinos are Dirac particles? (3) If neutrinoless double beta decay is observed with a large neutrino mass element, what is the total mass in neutrinos? (4) If neutrinoless double beta decay is observed, but next-generation beta decay searches for a neutrino mass only set a mass upper limit, can we establish whether the mass hierarchy is normal or inverted? We base our answers on the expected performance of next-generation neutrinoless double beta decay experiments and on simulations of the accuracy of calculations of nuclear matrix elements. [Phys. Rev. D **70**, 033012 (2004)]

From QFT to a disoriented chiral condensate. B. Bambah. *School of Physics, University of Hyderabad, Hyderabad-500 046, India;* C. Mukku , *Department of Mathematics and Department of Computer Science & Applications, Panjab University, Chandigarh-160014, India.* (Received 13 January 2004; published 17 August 2004)

A quantum field theoretical model for the dynamics of the disoriented chiral condensate is presented. A unified approach to relate the quantum field theory directly to the formation, decay, and signals of the DCC and its evolution is taken. We use a background field analysis of the $O(4)$ sigma model, keeping one-loop quantum corrections (quadratic order in the fluctuations). An evolution of the quantum fluctuations in an external, expanding metric which simulates the expansion of the plasma is carried out. We examine, in detail, the amplification of the low-momentum pion modes with two competing effects: the expansion rate of the plasma and the transition rate of the vacuum configuration from a metastable state into a stable state. We show the effect of DCC formation on the multiplicity distributions and the Bose-Einstein correlations. [Phys. Rev. D **70**, 034001 (2004)]

Heavy pentaquarks. P.-Z. Huang, Y.-R. Liu, W.-Z. Deng, and X.-L. Chen, *Department of Physics, Peking University, Beijing 100871, China;* Shi-Lin Zhu, *Department of Physics, Peking University, Beijing 100871, China, and The Key Laboratory of Heavy Ion Physics, Ministry of Education, China.* (Received 26 January 2004; revised manuscript received 2 April 2004; published 17 August 2004)

We construct the spin-flavor wave functions of the possible heavy pentaquarks containing an anticharm or antibottom quark using various clustered quark models. Then we estimate the masses and magnetic moments of the $J^P=\frac{1}{2}^+$ or $\frac{3}{2}^+$ heavy pentaquarks. We emphasize the difference in the predictions of these models. Future experimental searches at BESIII, CLEOc, BELLE, and LEP may find these interesting states. [Phys. Rev. D **70**, 034003 (2004)]

Light-front approach for heavy pentaquark transitions. Hai-Yang Cheng,[1] Chun-Khiang Chua,[1] and Chien-Wen Hwang[2] [1]*Institute of Physics, Academia Sinica, Taipei, Taiwan 115, Republic of China,* [2]*Department of Physics, National Kaohsiung Normal University, Kaohsiung, Taiwan 802, Republic of China.* (Received 23 March 2004; published 17 August 2004)

Assuming the two-diquark structure for the pentaquark state as advocated in the Jaffe-Wilczek model, there exist exotic parity-even antisextet and parity-odd triplet heavy pentaquark baryons. The theoretical estimate of charmed and bottom pentaquark masses is quite controversial and it is not clear whether the ground-state heavy pentaquark lies above or below the strong-decay threshold. We study the weak transitions of heavy pentaquark states using the light-front quark model. In the heavy quark limit, heavy-to-heavy pentaquark transition form factors can be expressed in terms of three Isgur-Wise functions: two of them are found to be normalized to unity at zero recoil, while the third one is equal to 1/2 at the maximum momentum transfer, in accordance with the prediction of the large-N_c approach or the quark model. Therefore, the light-front model calculations are consistent with the requirement of heavy quark symmetry. Numerical results are obtained for form factors and Isgur-Wise functions are presented. Decay rates of the weak decays $\Theta_b^+\to\Theta_c^0\pi^+(\rho^+)$, $\Theta_c^0\to\Theta^+\pi^-(\rho^-)$, $\Sigma_{5b}'^+\to\Sigma_{5c}'^0\pi^+(\rho^+)$, and $\Sigma_{5c}'^0\to N_8^+\pi^-(\rho^-)$ with Θ_Q, Σ_{5Q}', and N_8 being the heavy antisextet, heavy triplet, and light octet pentaquarks, respectively. For weakly decaying Θ_b^+ and Θ_c^0, the branching ratios of $\Theta_b^+\to\Theta_c^0\pi^+$ and $\Theta_c^0\to\Theta^+\pi^-$ are estimated to be at the level of 10^{-3} and a few percent, respectively. [Phys. Rev. D **70**, 034007 (2004)]

Single-inclusive jet production in polarized *pp* collisions at $\mathcal{O}(\alpha_s^3)$. B. Jäger and M. Stratmann, *Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany;* W. Vogelsang, *Physics Department, Brookhaven National Laboratory, Upton, New York 11973, USA, and RIKEN-BNL Research Center, Bldg. 510a, Brookhaven National Laboratory, Upton, New York 11973-5000, USA.* (Received 7 April 2004; published 18 August 2004)

We present a next-to-leading order QCD calculation for single-inclusive high-p_T jet production in longitudinally polarized *pp* collisions within the "small-cone" approximation. The fully analytical expressions obtained for the underlying partonic hard-scattering cross sections greatly facilitate the analysis of upcoming BNL-RHIC data on the double-spin asymmetry $A_{\mathrm{LL}}^{\mathrm{jet}}$ for this process in terms of the unknown polarization of gluons in the nucleon. We simultaneously rederive the corresponding QCD corrections to unpolarized scattering and confirm the results existing in the literature. We also numerically compare to results obtained with Monte Carlo methods and assess the range of validity of the "small-cone" approximation for the kinematics relevant at BNL-RHIC. [Phys. Rev. D **70**, 034010 (2004)]

Spin effects in diffractive $Q\bar{Q}$ production at BNL eRHIC. S. V. Goloskokov, *Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna 141980, Moscow region, Russia.* (Received 26 April 2004; published 18 August 2004)

We discuss quark-antiquark leptoproduction within a QCD two-gluon exchange model at small x. The double spin asymmetries for longitudinally polarized leptons and transversely polarized protons in diffractive $Q\bar{Q}$ production are analyzed at eRHIC energies. The predicted A_{lT} asymmetry is large and can be used to obtain information on the polarized generalized gluon distributions in the proton. [Phys. Rev. D **70**, 034011 (2004)]

Hard gluon damping in hot QCD. André Peshier* *Institut für Theoretische Physik, Universität Giessen, 35392 Giessen, Germany* (Received 12 May 2004; published 19 August 2004)

The gluon collisional width in hot QCD plasmas is discussed with emphasis on temperatures near T_c, where the coupling is large. Considering its effect on the entropy, which is known from lattice calculations, it is argued that the width, which in the perturbative limit is given by $\gamma\sim g^2\ln(1/g)T$, should be sizeable at intermediate temperatures but has to be small close to T_c. Implications of these results for several phenomenologically relevant quantities, such as the energy loss of hard jets, are pointed out. [Phys. Rev. D **70**, 034016 (2004)]

Chiral soliton model for arbitrary colors and flavors. Elizabeth Jenkins and Aneesh V. Manohar, *Department of Physics, University of California at San Diego, La Jolla, California 92093, USA.* (Received 18 February 2004; published 23 August 2004)

The semiclassical quantization of the chiral soliton model is studied for an arbitrary number of colors and flavors. The quantum numbers of the baryons in the soliton model are derived and are shown to agree with those in the constituent quark model for normal as well as exotic baryons. The general analysis elucidates the correct definition of exoticness for the three-flavor case, and allows one to interpret the soliton state in terms of quark model variables. The quantum numbers of all the allowed soliton states for the physically relevant case of three flavors are derived. [Phys. Rev. D **70**, 034023 (2004)]

Relativistic calculation of the meson spectrum: A fully covariant treatment versus standard treatments. Horace Crater, *The University of Tennessee Space Institute, Tullahoma, Tennessee 37388, USA;* Peter Van Alstine, *12474 Sunny Glen Drive, Moorpark, California 93021, USA.* (Received 21 November 2002; revised manuscript received 26 April 2004; published 26 August 2004)

A large number of treatments of the meson spectrum have been tried that consider mesons as quark-antiquark bound states. Recently, we used relativistic quantum ''constraint'' mechanics to introduce a fully covariant treatment defined by two coupled Dirac equations. For field-theoretic interactions, this procedure functions as a ''quantum mechanical transform of the Bethe-Salpeter equation.'' Here, we test its spectral fits against those provided by an assortment of models: Wisconsin model, Iowa State model, Brayshaw model, and the popular semirelativistic treatment of Godfrey and Isgur. We find that the fit provided by the two-body Dirac model for the entire meson spectrum competes with the best fits to partial spectra provided by the others and does so with the smallest number of interaction functions without additional cutoff parameters necessary to make other approaches numerically tractable. We discuss the distinguishing features of our model that may account for the relative overall success of its fits. Note especially that in our approach for QCD, the resulting pion mass and associated Goldstone behavior depend sensitively on the preservation of relativistic couplings that are crucial for its success when solved nonperturbatively for the analogous two-body bound states of QED. [Phys. Rev. D **70**, 034026 (2004)]

Accessing the longitudinally polarized photon content of the proton. A. Mukherjee and C. Pisano, *Institut für Physik, Universität Dortmund, D 44221 Dortmund, Germany.* (Received 12 May 2004; published 30 August 2004)

We investigate the QED Compton process in longitudinally polarized lepton-proton scattering both in the elastic and inelastic channels and show that the cross section can be expressed in terms of the polarized equivalent photon distribution of the proton. We provide the necessary kinematical constraints to extract the polarized photon content of the proton using this process at HERMES, COMPASS, and eRHIC. We also discuss the suppression of the major background process coming from virtual Compton scattering. We point out that such an experiment can give valuable information on $g_1(x_B, Q^2)$ in the small x_B, broad Q^2 region at the future polarized collider eRHIC and especially in the lower Q^2, medium x_B region in fixed target experiments. [Phys. Rev. D **70**, 034029 (2004)]

Nucleon masses and magnetic moments in a finite volume. Silas R. Beane, *Department of Physics, University of New Hampshire, Durham, New Hampshire 03824-3568, USA, and Jefferson Laboratory, 12000 Jefferson Avenue, Newport News, Virginia 23606, USA.* (Received 30 March 2004; revised manuscript received 28 May 2004; published 17 August 2004)

We compute finite-size corrections to nucleon masses and magnetic moments in a periodic, spatial box of size L, both in QCD and in partially quenched QCD. [Phys. Rev. D **70**, 034507 (2004)]

Topological approach to baryon-antibaryon and meson production in rapidly expanding Bjorken rods. G. Holzwarth, *Siegen University, 57068 Siegen, Germany.* (Received 26 April 2004; published 9 August 2004)

The topological approach to baryon-antibaryon production in the chiral phase transition is numerically simulated for rapidly expanding hadronic systems. For that purpose the dynamics of the effective chiral field is implemented on a space-rapidity lattice. The essential features of evolutions from initial ''hot'' configurations into final ensembles of (anti-)baryons embedded in the chiral condensate are studied in proper time of comoving frames. Typical times for onset and completion of the roll-down and exponents for the growth of correlations are extracted. Meson and baryon-antibaryon yields are estimated. For standard assumptions about initial coherence lengths they are compatible with experimental results. [Phys. Rev. D **70**, 036001 (2004)]

A naturally narrow positive-parity Θ^+. Carl E. Carlson, Christopher D. Carone, Herry J. Kwee, and Vahagn Nazaryan, *Particle Theory Group, Department of Physics, College of William and Mary, Williamsburg, Virginia 23187-8795, USA.* (Received 30 December 2003; published 18 August 2004)

We present a consistent color-flavor-spin-orbital wave function for a positive-parity Θ^+ that naturally explains the observed narrowness of the state. The wave function is totally symmetric in its flavor-spin part and totally antisymmetric in its color-orbital part. If flavor-spin interactions dominate, this wave function renders the positive-parity Θ^+ lighter than its negative-parity counterpart. We consider decays of the Θ^+ and compute the overlap of this state with the kinematically allowed final states. Our results are numerically small. We note that dynamical correlations between quarks are not necessary to obtain narrow pentaquark widths. [Phys. Rev. D **70**, 037501 (2004)]

Meson-baryon bound states in a (2+1)-dimensional strongly coupled lattice QCD model. Antônio Francisco Neto, *Departamento de Física e Informática, IFSC-USP, C.P. 369, 13560-970 São Carlos, SP, Brazil.* (Received 6 May 2004; published 18 August 2004)

We consider bound states of a meson and a baryon (meson and antibaryon) in lattice QCD in a Euclidean formulation. For simplicity, considering the + parity sector we analyze an SU(3) theory with a single flavor in 2+1 dimensions and two-dimensional Dirac matrices. We work in the strong coupling regime, i.e., in a region of parameters such that the hopping parameter κ is sufficiently small and $\kappa \gg g_0^{-2}$, where g_0^{-2} is the pure gauge coupling. There is a meson (baryon) particle with asymptotic mass $-2\ln\kappa$ ($-3\ln\kappa$) and an isolated dispersion curve. Here, in a ladder approximation, we show that there is no meson baryon (or meson-antibaryon) bound state solution to the Bethe-Salpeter equation up to the meson-baryon threshold ($\sim -5\ln\kappa$). The absence of such a bound state is an effect of a spatial range-one repulsive potential that is local in space at order κ^3, i.e., the leading order in the hopping parameter κ. [Phys. Rev. D **70**, 037502 (2004)]

Effect of bound dineutrons upon big bang nucleosynthesis. James P. Kneller and Gail C. McLaughlin, *Department of Physics, North Carolina State University, Raleigh, North Carolina 27695-8202, USA.* (Received 9 January 2004; published 17 August 2004)

We have examined the effects of a bound dineutron ^2n upon big bang nucleosynthesis (BBN) as a function of its binding energy B_{2_n}. We find a weakly bound dineutron has little impact but as B_{2_n} increases its presence begins to alter the flow of free nucleons to helium-4. Because of this disruption, and in the absence of changes to other binding energies or fundamental constants, BBN sets a reliable upper limit of $B_{2_n} \lesssim 2.5$ MeV in order to maintain the agreement with the observations of the primordial helium-4 mass fraction and D/H abundance. We also consider simultaneous variations in B_{2_n} and the deuteron binding energy B_D using a simplified BBN calculation. We demonstrate that only when B_D is very close to 1.7 MeV does the B_{2_n} upper limit increase to 3.5 MeV, a value set by incompatibility of an observed primordial $A=2$ abundance with the decay of deuterons. [Phys. Rev. D **70**, 043512 (2004)]

Two-loop hard-thermal-loop thermodynamics with quarks. Jens O. Andersen, *Institute for Theoretical Physics, University of Utrecht, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands;* Emmanuel Petitgirard, *Physics Department, Ohio State University, Columbus, Ohio 43210, USA;* Michael Strickland, *Institut für Theoretische Physik, Technische Universität Wien, Wiedner Hauptstrasse 8-10, A-1040 Vienna, Austria, and Physics Department, Duke University, Durham, North Carolina 27701, USA.* (Received 11 March 2003; published 9 August 2004)

We calculate the quark contribution to the free energy of a hot quark-gluon plasma to two-loop order using hard-thermal-loop (HTL) perturbation theory. All ultraviolet divergences can be absorbed into renormalizations of the vacuum energy and the HTL quark and gluon mass parameters. The quark and gluon HTL mass parameters are determined self-consistently by a variational prescription. Combining the quark contribution with the two-loop HTL perturbation theory free energy for pure glue we obtain the total two-loop QCD free energy. Comparisons are made with lattice estimates of the free energy for $N_f=2$ and with exact numerical results obtained in the large-N_f limit. [Phys. Rev. D **70**, 045001 (2004)]

Dimensionally reduced expression for the QCD fermion determinant at finite temperature and chemical potential. David H. Adams, *Instituut-Lorentz for Theoretical Physics, Leiden University, Niels Bohrweg 2, NL-2333 CA Leiden, The Netherlands.* (Received 23 March 2004; published 9 August 2004)

A dimensionally reduced expression for the QCD fermion determinant at finite temperature and chemical potential is derived which sheds light on the determinant's dependence on these quantities. This is done via a partial zeta regularization, formally applying a general formula for the zeta determinant of a differential operator in one variable with operator-valued coefficients. The resulting expression generalizes the known one for the free fermion determinant, obtained via Matsubara frequency summation, to the case of a general background gauge field; moreover there is no undetermined overall factor. Rigorous versions of the result are obtained in a continuous time–lattice space setting. The determinant expression reduces to a remarkably simple form in the low temperature limit. A program for using this to obtain insight into the QCD phase transition at zero temperature and nonzero density is outlined. [Phys. Rev. D **70**, 045002 (2004)]