THOMAS D. COHEN
Professor of Physics

Education:

B.Sc.	Harvard College, Cambridge, MA	1980
Ph.D.	University of Pennsylvania	1985

Experience in Higher Education:

1985-87	University of Maryland	Research Associate
1987-88	University of Maryland	Asst. Res. Scientist
1988-92	University of Maryland	Assistant Professor
1992-97	University of Maryland	Associate Professor
1994-95	University of Washington and the Institute for Nuclear Theory, Seattle	Visiting Scientist
1997-	University of Maryland	Professor
2009-	Maryland Center for Fundamental Physics, University of Maryland	Director
2009-	University of Maryland	Assoc. Chair for Graduate Education

Synergistic Activities:

Director, Maryland Center for Fundamental Physics. This state supported center is aimed at promoting synergies between studies in various subfields of theoretical physics including nuclear, physics, particle physics, cosmology and gravitation (2009-).

Editorial Board, Physical Review C (2008-)

Convener, "QCD and nuclear physics" section at "Quark Confinement and the Hadron Spectrum" (2006,2008,2010)

Co-organizer, "Large Nc QCD" program at GGI (program in 2011) (Florence)

Convener, "Large N_C QCD" session at "Continuous Advances in QCD", Minneapolis (May 2006)

Recent Research

During the past year Prof. Cohen's research has focused predominantly on aspects of large N_c QCD. Two of these projects involve nuclear matter in the large N_c limit—one of these focusing on the regime where the quark masses are large and the other on the regime where the quark masses are small. The third completed piece of research was on the Hagedorn spectrum in large N_c QCD. In addition, he is currently working on several projects which are likely to come to fruition in the near term.

A. The Hagedorn Spectrum and Large Nc QCD in 2+1 and 3+1 Dimensions

This work [1] is an extension of Prof. Cohen's earlier work showing that a Hagedorn spectrum is required in large N_c assuming several standard assumptions [2]. In this work we showed that a Hagedorn spectrum (i.e., spectrum where the number of hadrons grows exponentially with the mass) emerges automatically in large N_c QCD in 2+1 and 3+1 dimensions. The approach is based on the study of Euclidean space correlation functions for composite operators constructed from quark and gluon fields and exploits the fact that the short time behavior of the correlators is known in QCD. The demonstration relies on one critical assumption: that perturbation theory accurately describes the trace of the logarithm of a matrix of point-to-point correlation functions in the regime where the perturbative corrections to the asymptotically free value are small. The formulation here is both more transparent than the one in [2], and it generalizes that work to the theoretically interesting case of QCD in 2+1 dimensions.

This work was done in collaboration with graduate student Vojtech Krejcirik.

[1] T. D. Cohen and V. Krejcirik, submitted to JHEP, DOE/ER/40762-496 (Apr. 2011) [arXiv:1104.4783 [hep-ph]].
[2] T. D. Cohen, JHEP **06**, 098 (2010) [hep-th/0901.0494].

B. Chiral Symmetry Restoration at Finite Density in Large N_c QCD

At large N_c , cold nuclear matter is expected to form a crystal and thus spontaneously break translational symmetry. The description of chiral symmetry breaking and translational symmetry breaking can become intertwined. Here, the focus was on aspects of chiral symmetry breaking and its possible restoration that are by construction independent of the nature of translational symmetry breaking—namely spatial averages of chiral order parameters. A system was to be considered to be chirally restored provided all spatially-averaged chiral order parameters are zero. A critical question is whether chiral restoration in this sense is possible for phases in which chiral order parameters are locally non-zero but whose spatial averages all vanish. We showed that this is not possible unless all chirally-invariant observables are spatially uniform. This result is first derived for Skyrme-type models, which are based on a nonlinear sigma model and by construction break chiral symmetry on a point-by-point basis. A no-go theorem for chiral restoration (in the average sense) for all models of this type is obtained by showing that in these models there exist chirally symmetric order parameters which cannot be spatially uniform. More significantly we showed that the no-go theorem applies to large N_c QCD in any phase which has a non-zero but spatially varying chiral condensate. The theorem is demonstrated by showing that in a putative chirally-restored phase, the field configuration can be reduced to that of a nonlinear sigma model. We also showed why previous arguments based on the Skyrme model apparently demonstrating chiral restoration in this averaged sense are consistent with the theorem. In cases where the Skyrme model for finite density was approximated as a single Skyrmion on a hypersphere we showed that the system was chirally restored in the average sense but that this was an artifact of the ad hoc—and unphysical—hypersphere approximation. For the case of Skyrmions in free space we showed that although the usually chiral condensate can vanish when spatially averaged—and will for high enough density—other chiral order parameters do not.

This work was done in collaboration with Prabal Adhikari (graduate student), Mark C. Strother (undergraduate and soon to be Berkeley graduate student) and Raja R. M. Ayyagari (Poolesville High School student and soon to be Maryland undergraduate.)

[1] P. Adhikari, T. D. Cohen, R. R. M. Ayyagari, M. C. Strother, Phys. Rev. C **83**, 065201 (2011). [arXiv:1104.2236]

C. Baryons and Baryonic Matter in the Large N_c and Heavy Quark Limits

This research explored properties of baryons and finite density baryonic matter in an artificial world in which N_c, the number of colors, is large and the quarks of all species are degenerate and much larger than $\Lambda_{\rm QCD}$. It has long been known that in large N_c QCD, baryons composed entirely of heavy quarks are accurately described in the mean-field approximation. However, the detailed properties of baryons in the combined large N_c and heavy quark limits have not been fully explored. Here some basic properties of baryons were computed using a variational approach. At leading order in both the large N_c and heavy quark expansions the baryon mass is shown to be $M_{\rm baryon} \approx N_c M_Q \left(1 - 0.05426\, \tilde{\alpha}_s^2\right)$ where $\tilde{\alpha}_s \equiv N_c \alpha_s$. The baryon form factor is also computed. Baryonic matter, the analog of nuclear matter in this artificial world, should also be well described in the mean-field approximation. In the special case where all baryons have an identical spin flavor structure, it was shown that in the formal heavy quark and large N_c limit, interactions between baryons are dominated by Pauli principle effects and are strictly repulsive at low densities. The energy per baryon was computed in this limit and found to be exponentially small. It was shown that when the restriction to baryons with an identical spin-flavor structure is dropped, a phase of baryonic matter exists with a density of $2N_f$ times that for the restricted case but with the same energy (where N_f is the number of degenerate flavors). It was shown that this phase is at least metastable. It was also shown that while in the strict large N_c limit there is at least a metastable phase which does not saturate. However, if one first takes the large M_Q limit and then works at next-to-leading order in large N_c the system will saturate with the saturation density and binding energy per nucleon going to zero as N_c goes to infinity.

This work was done in collaboration with Kamal Ndousse (a Montgomery Blair High School student now an MIT undergraduate) and Nilay Kumar (a Montgomery Blair High School student soon to be a Columbia undergraduate.)

[1] T. D. Cohen, N. Kumar, and K. Ndousse, DOE/ER/40762-493, accepted for publication in Phys. Rev. C (2011) [arXiv:1102.2197 [nucl-th]]