Strong Dynamics and Dynamical Chiral Symmetry Breaking

Investigators:
ANL: Craig Roberts (PHY), Donald Sinclair (HEP), Cosmas Zachos (Argonne)
U of C: Jeff Harvey, David Kutasov
Sophia Domokos (Grad. Student), Andy Royston (Grad. Student)
ANL-HEP & U of C: Carlos Wagner

Progress report

6.1 Workshop (June 4-5, 2007)

http://www.hep.anl.gov/czachos/ChiralStrongJTI.html

We organised a two-day workshop to promote our multi-expertise collaborative project on Chiral Symmetry Breaking in the strong interactions. Including the six investigators in our group, there were twenty-eight participants. Twelve talks were presented, reporting on novel insights and methods: AdS/CFT duality of large-N_c QCD to a gravity on AdS5, lattice-QCD and Dyson-Schwinger approaches. The possibility of a separation between the mass-scales associated with confinement and dynamical chiral symmetry breaking was much canvassed, as were the viscosity/entropy ratio in the quark-gluon medium and the ability and challenge of connecting theory with real-world experiments at modern facilities.

Discussions at the workshop led to a new collaboration between J. Harvey (U of C) and Chris Hill and Richard Hill (Fermilab) on novel anomalous interactions in the Standard Model at high baryon densities. They found that there is a new anomaly-related coupling between the photon and the electroweak Z-boson whose strength is proportional to the baryon density. They are in the process of studying possible applications of this coupling, including neutron star cooling and new methods of neutrino detection. There are also possible applications to axion detection.

6.2 Graduate student

Our student, Eduard Antonyan, in collaboration with Sophia Domokos, has been investigating intersecting D-brane systems which, as in QCD, manifest both dynamical breaking of chiral symmetry and explicit breaking through fermion mass terms. No specific results have yet been achieved, but this is an important step in making more realistic strong coupling dual descriptions of QCD.

6.3 Postdoctoral fellow

We received funds from the JTI in Feb., 2007. This was too late for us to make an offer to either of the two high-quality candidates with whom we'd been communicating. Nevertheless, with the arrival of the funds, we renewed our search. An advertisement went out within one month and by the end of April we were in discussions with an excellent candidate. Once we were able to satisfy this candidate on security of appointment, as described below, an offcial offer was made. It was accepted on 13 Jun., so that Dr. Alexander Velytsky, most recently from UCLA, will begin to work with our

group on 1st Sept., 2007. An earlier start would have been impossible without Velytsky breaking agreements with his current employer.
Before describing his credentials, we will explain the funding arrangements we have made.
Following advice from the JTI Board, we spent the FY07 portion of the postdoc salary on staff effort, split evenly between PHY and HEP. Through this expedient, we have effectively carried-over one year of support into FY08 for the postdoc. In order to convince Velytsky to accept our offer, we guaranteed him two years of support. If, for any reason, the JTI is unable to renew our request, Velytsky will be supported through till the end of FY09: one-quarter support from PHY, one-quarter from HEP, and one-half from the U. of Chicago.

Dr. Velytsky has research experience that covers a broad range of topics in lattice-QCD, both from the computational and the theoretical side, and an excellent publication record for one at this early stage in his career. He comes to us highly recommended by his earlier associates.

Dr. Velytsky's research abilities should enable him to make significant contributions in understanding those non-perturbative properties of QCD which can be independently predicted from the holographic approach to string/brane theory. For this, the techniques of lattice QCD simulations show excellent promise.

The string/brane approach suggests that, if one includes four-fermion interactions in QCD, it should be possible to vary the scale of chiral symmetry breaking independently of the scale of confinement. Most lattice QCD simulations indicate that these two scales are identical. However, work by one of us (DKS), suggests that for large four-fermion couplings the chiral symmetry breaking length scale might become shorter than the confinement scale. The larger-lattice simulations that are now possible should enable us to confirm this. This is to be the first project that Velytsky will undertake. While this project is underway, he will be encouraged to become familiar with the string/brane approach and nonperturbative methods for studying continuum QCD. This will broaden his knowledge of different areas of high-energy/nuclear theory and enable him to define his own research path within our project. His experience with programming the QCDOC computer should enable him to use Argonne's IBM BlueGene, should its resources become available to the Argonne community.

6.4 Publications

Since our proposal was submitted, the following articles related to this research theme have been released:

1. C. K. Zachos, \A Classical Bound on Quantum Entropy," J. Phys. A 40, F407 (2007).

2. D. K. Sinclair, \Equilibrium thermodynamics of lattice QCD," arXiv:hep-lat/0701010.

3. M. Carena, E. Ponton, J. Santiago and C. E. M. Wagner, \Electroweak constraints on warped models with custodial symmetry," arXiv:hep-ph/0701055.

4. S. K. Domokos and J. A. Harvey, \Baryon number-induced Chern-Simons couplings of vector and axial-vector mesons in holographic QCD," arXiv:0704.1604 [hep-ph].

5. M. A. Ivanov, J. G. Korner, S. G. Kovalenko and C. D. Roberts, \B- to light-meson transition form factors," arXiv:nucl-th/0703094.

6. A. Giveon and D. Kutasov, \Gauge symmetry and supersymmetry breaking from intersecting branes," arXiv:hep-th/0703135.

7. A. D. Medina, N. R. Shah and C. E. M. Wagner, \Gauge-Higgs Unification and Radiative Electroweak Symmetry Breaking in Warped Extra Dimensions," arXiv:0706.1281 [hep-ph].

They have naturally arisen from existing collaborations but the number and thematic diversity highlights the potential for interaction and cross-fertilisation within our group and the wider Chicago strong-interaction community.