Proposal for GGI Workshop in Spring 2008

"Non-Perturbative Methods in Strongly Coupled Gauge Theories"

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Abstract

We propose to hold a workshop in the spring of 2008 entitled "Non-Perturbative Methods in Strongly Coupled Gauge Theories". The workshop will run for approximately 2.5 months, with 30 – 40 participants present at any given time. Its main objective is to bring together researchers working on lattice QCD, continuum quantum field theory (including field theory at finite temperature, solitons and other classical solutions, and supersymmetry) and string theory, with the purpose of advancing our understanding of strongly coupled gauge systems.

Scientific Motivation

In recent years there has been a remarkable convergence of ideas in gauge theory, string theory and gravity which date back more than thirty years.

The numerical study of Quantum Chromodynamics (QCD) has matured into a reliable tool for studying the theory at its natural scale. Lattice QCD can now be used to calculate many interesting observables and compare them to experiment. It is also very useful for testing theoretical ideas about the behavior of the theory, in particular about confinement.

At the same time, the ongoing RHIC experimental program at Brookhaven has been producing new results on the behavior of quarks and gluons at temperatures and densities of order the QCD scale, and additional results are expected from planned future experiments at CERN and elsewhere.

Theoretical studies of strongly coupled gauge theories have also undergone dramatic development in recent years following the discovery of the duality between gauge theory and string theory. Higher dimensional gravitational techniques – once the preserve of formal string theorists – now play a key role in our understanding of strongly coupled four dimensional quantum field theories. Since the advent of the AdS/CFT correspondence, generalizations have been proposed to confining theories, theories at finite temperature and theories with dynamical quarks.

These developments have already led to increased communication between the experimental, lattice QCD and string communities and there have been a number of recent successes at the interface between the different fields. These include:

- Applications of the AdS/CFT correspondence to the study of the strongly interacting quark-gluon plasma produced at RHIC. While input from the lattice on hot QCD is broadly used to understand this phenomenon, gravity techniques have proven useful in modeling heavy quark diffusion and quenching, as well as viscosity and other transport coefficients.

- The development of the original AdS/CFT correspondence towards more realistic QCD-like theories, often referred to as AdS/QCD. This has led to recent progress in computing aspects of hadron spectroscopy which can be compared favorably to lattice data.

- Renewed interest in the confinement mechanism and the role played by topological objects such as instantons, monopoles and vortices. Lattice simulations provide insight into the nature of the vacuum both above and below the deconfinement transition. This may be compared with exact results from continuum models.

We believe that further interaction between these communities is important for the future of the field. The lattice community can benefit from the development of a framework which can provide a qualitative picture of the dynamics of QCD in which some quantities can be calculated analytically and compared to lattice results, and which can be used to formulate new questions about the theory. Researchers working on QCD strings can use lattice and experimental results as data to be explained by string theory and guide its development. Furthermore, the theoretical advances can be used to make new predictions that can be tested in future experiments and lattice simulations.

Aims of the Workshop

One of the main purposes of the workshop we are proposing is to facilitate further interactions between the different communities. We feel strongly that the time is ripe for such a meeting, with the need to "cross-pollinate" between these communities growing ever stronger. This will allow important results in each community to be advertised to a wider audience and set the agenda for future work.

We expect one of the general themes of the workshop to be the comparison of the predictions of lattice and continuum techniques for the dependence of observables such as masses of hadrons, the chiral condensate, and other properties of the quark-gluon plasma on the temperature, chemical potential, etc. There is also interest in studying gauge theories with large number of colors on the lattice, and such studies should be even more amenable to continuum analysis.

The precise topics to be discussed will necessarily be determined, in part, by the organizers and participants at the time of the workshop. Likely topics of interest include:

- An exploration of the origin and extent of the phenomenological success of applying supergravity techniques to analyze the properties of QCD. Typically these backgrounds are not directly related to QCD, yet capture much of the crucial physics. A better understanding of this can help in finding and analyzing other backgrounds of string theory which are even better suited for studying strongly coupled gauge theory.

- Integrability in large N_c gauge theories. This may provide exact results for the dynamics of theories such as $N = 4$ super Yang Mills, and lead to new insights into the dynamics of strongly coupled gauge theories in general. We expect this subject to receive attention at the workshop as well.

- The development of new techniques to simulate supersymmetric theories on the lattice. These theories have long been favorite "toy models" for QCD, exhibiting much of the interesting dynamics in a more controlled setting.

More generally, we hope that interactions at the workshop will help the participants to identify new questions that can be tackled using the different techniques described above and would stimulate more work. Finally, the experimental program at LHC is going to address the dynamics of electroweak symmetry breaking and, hopefully also that of supersymmetry breaking. These subjects are also likely to be addressed at the workshop.

Preliminary list of participants

Of the organizers listed at the beginning A. Di Giacomo and V. Zakharov would remain in residence for most of the program. D. Kutasov, E. Shuryak and D. Tong would commit to spend at least one month at the program.

We have surveyed a number of key potential participants in this program and have found overwhelming support among the lattice, QCD and string communities. The following people expressed an interest to participate in the workshop:

O. Aharony (Weizmann Inst.), N. Beisert (Potsdam, MPI), C. Gattringer (Graz U.), T. DeGrand (Colorado U.), M. D'Elia (Genoa U. & INFN Genoa), N. Dorey (Cambridge U.), F. Gliozzi (INFN, Turin), F. Gubarev (Moscow, ITEP), J. Greensite (San Fransisco State U.), S. Gubser (Princeton U.), A. Hanany (Perimeter Inst.), J. Harvey (Chicago U.), T. Hollowood (Swansea U.), M. Ilgenfritz (Humboldt U., Berlin), K. Intriligator (UC, San Diego), R. Janik (Jagiellonian U.), A. Karch (Washington U., Seattle), I. Klebanov (Princeton U.), K. Konishi (Pisa U. & INFN, Pisa), D. Lust (Munich, MPI & Munich U.), J. Maldacena (IAS, Princeton), D. Mateos (UC Santa Barbara), S. Minwalla (Tata Inst.), R. Myers (Perimeter Inst.), J. Negele (MIT), M. Polikarpov (Moscow, ITEP), K. Rajagopal (MIT & LBL, Berkeley), N. Seiberg (Princeton, IAS), M. Shifman (Minnesota U.), D.T. Son (Washington U., Seattle), M. Staudacher (Potsdam, MPI), M. Stephanov (Illinois U., Chicago), M. Strassler (Washington U., Seattle), M. Teper (Oxford U.), A. Tseytlin (Imperial, London), P. van Baal (Leiden U.), and L. Yaffe (Washington U., Seattle).

We further plan to invite as many younger people, particularly postdocs but also students, as possible. We believe that the participation of young, vibrant researchers in the discussion sessions and informal interactions should be very useful – both for them and for the more senior researchers.

Workshop Schedule

We intend to run the workshop in a flexible manner, with plenty of time devoted to informal discussions and meetings in order to emphasize common open problems shared by the participants. This format is crucial if the interactions between the different communities are to thrive, allowing the multi-dimensional nature of the workshop to succeed. The number of talks will be limited to four a week. These will be given by workshop participants and will be 1 – 1.5 hours long. More informal discussion sessions will be organized at the initiative of the participants and organizers.

We further propose to hold a one week conference around the start of the workshop (possibly the last week of March 2008). The purpose of the conference is to familiarize the participants with

the main research topics in the different subfields relevant to the workshop. This is particularly important since the workshop is intended to include members from rather different communities, for whom mutual interaction is possibly a rare event. The conference will present an opportunity for members of the different communities to learn the language and techniques of the others. For this reason, we hope to include a number of introductory talks, reviewing the status of the the different fields — including RHIC experiments, lattice QCD and AdS/CFT — with emphasis on what has been achieved, what one can hope to achieve, and what issues require conceptual breakthroughs. There will, of course, also be more technical talks, covering the latest developments in the different fields.