NATO Advanced Study Institute
and
Isaac Newton Institute Workshop

CONFINEMENT, DUALITY AND NON-PERTURBATIVE ASPECTS OF QCD

Edited by

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PREFACE

Before you lies the proceedings of the NATO Advanced Study Institute/Newton Institute Workshop “Confinement, duality and non-perturbative aspects of QCD”. The school covered the most important techniques to study Quantum Chromodynamics (QCD) and confinement, from lattice gauge theory, through Wilson's renormalisation group, to electromagnetic duality. The organising committee existed of: Ian Drummond (DAMTP, Cambridge), Mikhail Shifman (Minneapolis), Peter West (King's, London) and Pierre van Baal (Leiden), who acted as director of the school.

This summerschool was the concluding activity of a six month programme on “Non-perturbative Aspects of Quantum Field Theory” taking place at the Isaac Newton Institute for Mathematical Sciences in Cambridge, UK, which started in January 1997, organised by David Olive, Pierre van Baal and Peter West. A large number of the lecturers also participated in the programme and a few programme participants were asked to present a seminar at the school. Not contained in these proceedings are the seminars by Peter Landshoff (DAMTP, Cambridge) on “The Pomeron” and by Ludwig Faddeev (Steklov Math. Inst., St. Petersburg) on “Knot-like solitons in 3+1 dimensional field theory”. In addition to the lectures and seminars there were two poster sessions at which participants presented their work. Authors and titles of these posters are listed on a separate page.

These proceedings address the long standing question of understanding how quarks are confined within subnuclear particles. It covers aspects of hadron spectroscopy, of the running of the strong coupling constant and of the Wilson renormalisation group, setting out the framework in which non-perturbative issues in QCD should be discussed. The renormalisation group is discussed in the context of the lattice, momentum-cutoff and light-front approaches. Instantons feature prominently in the context of a successful low-energy description for QCD. Some of these properties relevant to chiral symmetry breaking are universal and can be captured in random matrix models. Another important theme that is represented in these proceedings is the conjecture that monopoles condensate, such that QCD behaves as a dual superconductor. These proceedings address how the so-called abelian projection introduced fifteen years ago by 't Hooft, might provide an explicit scenario to test this dual superconductor picture. The recent Seiberg-Witten duality results add a new dimension to this conjecture. Supersymmetry has developed into an important tool to learn more about non-perturbative aspects of field theories. In the presence of supersymmetry, both instantons and monopoles will contribute in very special ways, revealing deep results relevant for the dynamics of the theory. It is hoped that some of these lessons are relevant to QCD.

This school was unique in bringing so many different approaches together, each expected to carry part of the solution towards the confinement problem. Any student that wishes to make progress on the confinement problem should be aware of these approaches. The lectures are ordered as much as possible so as to assist the reader in acquiring the necessary background, assumed known in some of the lectures.

This school would not have taken place without the generous financial support of NATO. I also thank the Newton Institute for financial and administrative support, in particular its conference secretary, Heather Dawson who has been of much help. Also I would like to thank DAMTP and in particular David Harris to provide computer access for the participants during the school. I am grateful to all the lecturers for their efforts to make this school and the proceedings in a successful one. Last but not least I thank all students for their enthusiastic participation in this summerschool.

Pierre van Baal.

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List of Posters

- *Attilio Cucchieri* - Infrared behavior and Gribov noise for gluon and ghost propagators in minimal Landau gauge
- *Cesar Fosco* - On bosonization in higher dimensions
- *Amit Ghosh* - Understanding the area proposal for extremal black hole entropy
- *Elena Gubankova* - Modified similarity renormalization
- *Adam Halasz* - Higher order level statistics in lattice QCD spectra
- *Alistair Hart* - Ehrenfest theorems for field strength and electric current in Abelian projected SU(2) gauge theory
- *Ronald Horgan* - The nature of the continuum limit in 2D-RP(n) models
- *Alfonso Jaramillo* - Confinement through a local vacuum wave functional
- *Seikou Kato* - Various representations of infrared effective lattice QCD
- *Jani Lukkarinen* - Lattice simulations of the microcanonical ensemble
- *Manu Mathur* - Magnetic monopoles, gauge invariant dynamical variables and the Georgi-Glashow model
- *Myckola Schwetz* - Softly Broken SQCD
- *Peter Skala* - Confinement and colour magnetic currents in QCD
- *Matthew Slater* - One-instanton tests of the exact results in N=2 supersymmetric QCD
- *Corneliu Sochichiu* - On the connection between symplectic form and commutator anomaly for chiral SU(N) Yang-Milss models
- *Tanmay Vachaspati* - The dual standard model
- *Federica Vian* - How to compute the chiral anomaly without breaking global chiral symmetry
- *Thomas Waindzoch* - Collective coordinate description of soliton dynamics
- *Axel Weber* - The heavy quark potential from Wilson's exact renormalization group
- *Maxim Zabzine* - Zamolodchikov's C-theorem and phase transitions
- *Martin Zach* - Flux tubes in dually transformed U(1) lattice gauge theory - Do they attract or repel each other?

Lecturers	
Adriano Di Giacomo - INFN, Pisa, Italy	Mikhail Shifman - Minneapolis, US
Ludwig Faddeev - St.Petersburg, Russia	Edward Shuryak - Stony Brook, US
Peter Hasenfratz - Bern, Switzerland	Tsuneo Suzuki - Kanazawa, Japan
Gerard 't Hooft - Utrecht, The Netherlands	Michael Teper - Oxford, UK
Richard Kenway - Edinburgh, UK	Pierre van Baal - Leiden, The Netherlands
Peter Landshoff - DAMTP, Cambridge, UK	Jac Verbaarschot - Stony Brook, US
Peter Lepage - Cornell Univ., US	Peter Weisz - MPI, Munich, Germany
Chris Michael - Liverpool, UK	Peter West - King's, London, UK
Robert Perry - Ohio State Univ., US	Christof Wetterich - Heidelberg, Germany
Mikhail Polikarpov - ITEP, Moscow, Russia	Daniel Zwanziger - NYU, New York, US
Adam Schwimmer - Weizmann Institute, Israel	

Students	
Gert Aarts - Utrecht, The Netherlands	Jani Lukkarinen - Helsinki, Finland
Tom Albert - Bonn, Germany	Thomas Manke - Cambridge, UK
Avetis Avakyan - Yerevan, Armenia	Fotini Markopoulou - Imperial, UK
Zoltan Bajnok - Budapest, Hungary	Manu Mathur - Pisa, Italy
Massimiliano Baldicchi - Milano, Italy	Christopher Maynard - Edinburgh, UK
Silas Beane - Maryland, US	Shiraz Minwalla - Princeton, US
Roberto Begliuomini - Trento, Italy	Vapharsh Mkhitaryan - Yerevan, Armenia
Andree Blotz - Los Alamos, US	Leszek Motyka - Krakow, Poland
Martina Brisudova - Los Alamos, US	Guido Mueller - Bonn, Germany
Stephane Bronoff - Marseille, France	Avijit Mukherjee - Brandeis, US
Boris Chibisov - Minneapolis, US	Shinsuke Nishigaki - NBI, Copenhagen, Denmark
Attilio Cucchieri - Bielefeld, Germany	Thomas Pause - Regensburg, Germany
Aldo Deandrea - Marseille, France	Mike Peardon - Kentucky, US
Luigi Del Debbio - Marseille, France	Petrus Pennanen - Helsinki, Finland
Massimo Di Pierro - Southampton, UK	Adam Ritz - Imperial, UK
Frank Ferrari - LPTENS, Paris, France	Joao Rodrigues - Lisbon, Portugal
Cesar Fosco - Bariloche, Argentina	Sinead Ryan - Fermilab, US
Martyn Foster - Liverpool, UK	Ricardo Schiappa - MIT, Boston, US
Amit Ghosh - Calcutta, India	Frederik Scholtz - Stellenbosch, South Africa
Harald Griesshamer - Erlangen, Germany	Myckola Schwetz - Yale, US
Elena Gubankova - Heidelberg, Germany	Konstantin Selivanov - ITEP, Moscow, Russia
Miklos Adam Halasz - Stony Brook, US	Melih Sener - Stony Brook, US
Anthony Hams - Groningen, The Netherlands	Sergei Shabanov - FU Berlin, Germany
Alistair Hart - Louisiana, US	Peter Skala - Vienna, Austria
Ronald Horgan - Cambridge, UK	Matthew Slater - Durham, UK
Edmund Iancu - Saclay, France	Corneliu Sochichiu - JINR, Dubna, Russia
Alfonso Jaramillo - Valencia, Spain	Mikhail Stephanov - Urbana-Champaign, US
Dirk Jungnickel - Heidelberg, Germany	Kazunori Takenaga - Kobe, Japan
Seikou Kato - Kanazawa, Japan	Sergey Troitsky - INR, Moscow, Russia
Arjan Keurentjes - Leiden, The Netherlands	Tanmay Vachaspati - Case Western, US
Elyakum Klepfish - King's, London, UK	Federica Vian - Parma, Italy
Stefano Kovacs - Tor Vergata, Rome, Italy	Thomas Waindzoch - Darmstadt, Germany
Markus Leibundgut - Bern, Switzerland	Axel Weber - Mexico, Mexico
Maxim Libanov - INR, Moscow, Russia	Pawel Wegrzyn - Krakow, Poland
David Lin - Edinburgh, UK	Maxim Zabzine - St.Petersburg, Russia
Daniel Litim - Imperial, UK	Martin Zach - Vienna, Austria
Carlos Lozano - Santiago de Compostela, Spain	