On Improvement in the Study of the Lattice Gluon Propagator

Patrick Oswald Bowman

Department of Physics and Mathematical Physics

November 14, 2000
Contents

Abstract v

Acknowledgements vii

1 Introduction 1

2 Building a Lattice Gauge Theory 5
   2.1 The Lattice regularisation 6
   2.2 Connecting with the continuum 10
   2.3 Fermions 13
   2.4 Generating gauge configurations 15

3 Improving the Lattice Approximation 17
   3.1 Symanzik improvement 18
   3.2 Mean-Field improved perturbation theory 19

4 Gauge Fixing on the Lattice 21
   4.1 Landau gauge 21
   4.2 A gauge fixing algorithm 24
   4.3 Gauge ambiguities 29

5 Discretisation errors in Gauge Fixing 33
   5.1 Alternative gauge fixing functionals 33
CONTENTS

5.2 Generic gauge fixing functional ................................. 35
5.3 Measuring discretisation errors ................................. 37
5.4 Behaviour of the algorithms .................................... 44

6 The Lattice Gluon Propagator .................................... 53
6.1 The Landau gauge gluon propagator ............................ 54
6.2 Lattice simulation ................................................ 57
6.3 Comparison of results ............................................ 66
6.4 Gribov noise ....................................................... 74

7 Confinement ............................................................ 79
7.1 Explicit confinement ............................................... 79
7.2 Confinement by stealth .......................................... 80
7.3 Conclusion ......................................................... 82

8 Summary and Outlook ................................................ 85

A CM Fortran Code for Landau Gauge Fixing ..................... 87

B Related Papers by the Author ................................... 167
Abstract

The infrared behaviour of the gluon propagator has been the subject of much speculation over the last twenty years. The non-linear nature of Quantum Chromodynamics combine with its characteristic strong coupling to make calculations difficult. Lattice gauge theory is the only known, \textit{ab initio} way of nonperturbatively calculating the objects of a quantum field theory, such as the propagators. Lattice gauge theory has had many successes, but the computational cost of simulating a large volume means that the long range (low momentum) behaviour of the gluon propagator is difficult to reliably access. Through the use of an improved action, with corresponding Landau gauge fixing and tree-level improvement, we obtain good signal on a set of coarse lattices, for modest computational cost. This enables us to simulate a large volume, and hence obtain good resolution in the infrared. We obtain a gluon propagator that, in Landau gauge, is finite in the infrared, and a detailed analysis indicates that the lattice artefacts are small.