

Bose-Einstein condensation from a gluon transport equation

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Abstract. We present a novel numerical scheme to solve the QCD Boltzmann equation in the soft scattering approximation, for the quenched limit of QCD. Using this we can readily investigate the evolution of spatially homogeneous systems of gluons distributed isotropically in momentum space. We numerically confirm results of Blaizot et al [1, 2], in particular that for so-called “overpopulated” initial conditions, a (transient) Bose-Einstein condensate could emerge during equilibration, in a finite time. Beyond that, we analyze the dynamics of the formation of this condensate. The scheme is extended to systems with cylindrically symmetric momentum distributions, in order to investigate the effects of anisotropy. In particular, we compare the rates at which isotropization and equilibration occur. We also compare our results from the soft scattering scheme to the relaxation time approximation.

1. Introduction

The study of quark-gluon plasma (QGP), the phase of strongly interacting matter formed as a result of relativistic nuclear collisions and consisting of quasi-free quarks and gluons, is of increasing relevance in modern physics [3]. It represents a testing ground for the Standard Model, as well as for finite temperature field theory and possible grand unification theories. It is also of cosmological significance, as the early universe was dominated by this phase of matter.

Experiments at the Relativistic Heavy Ion Collider (RHIC) and Large Hadron Collider (LHC) allow us to probe the energy scales at which the QGP is produced. Inferring its properties and phenomenological behaviour is a central goal of the heavy ion programs at these facilities. The theoretical tools that have been developed to describe it are manifold, as the various stages of a heavy ion collision represent very different physical regimes that demand similarly diverse mathematical formalisms to describe (see Fig. 1).

Prior to the collision, the nuclei are accelerated to near-light speed, with a Lorentz factor on the order of 100. They are therefore subject to strong Lorentz contraction along the beam axis. At these energies, the lifetime of gluons emitted from the valence quarks or other gluons is long enough to allow additional emissions of soft gluons from themselves. This process keeps increasing the number density of gluons until saturation occurs as recombination of gluons becomes non-negligible, forming the state of matter called the Color Glass Condensate (CGC). This regime of large gluon number is well approximated by classical dynamics [4-6].

In the following stage, a large number of gluons are liberated from the CGC. These gluons form a dense, off-equilibrium state called the glasma. Extensive hydrodynamic analyses of HIC indicate that as the medium expands, rapid thermalization occurs (characteristic time on

