Numerical insights into isotropization

Mario Araújo

Max-Planck Institut für Physik

19 April 2013

Ongoing work with David Mateos (UB) and Michal Heller (UvA).

Introduction

Motivation

QGP behaves as a strongly coupled system. RHIC has shown that it isotropizes very quickly. We do not know why!

Introduction

Motivation

QGP behaves as a strongly coupled system. RHIC has shown that it isotropizes very quickly. We do not know why!

Aim

Try to understand short isotropization time.

Introduction

Motivation

QGP behaves as a strongly coupled system. RHIC has shown that it isotropizes very quickly. We do not know why!

Aim

Try to understand short isotropization time.

Roadmap to computations

- QCD is hard. Use toy model:
  $\mathcal{N} = 4$ SYM $\rightarrow$ AdS/CFT comes into play

Introduction

Motivation

QGP behaves as a strongly coupled system. RHIC has shown that it isotropizes very quickly. We do not know why!

Aim

Try to understand short isotropization time.

Roadmap to computations

- QCD is hard. Use toy model:
  $\mathcal{N} = 4$ SYM $\rightarrow$ AdS/CFT comes into play
- Can model evolution of far-from-equilibrium plasma (isotropization) on the gravity side as formation and evolution of a BH.

Introduction

Motivation

QGP behaves as a strongly coupled system. RHIC has shown that it isotropizes very quickly. We do not know why!

Aim

Try to understand short isotropization time.

Roadmap to computations

- QCD is hard. Use toy model:
  $\mathcal{N} = 4$ SYM $\rightarrow$ AdS/CFT comes into play
- Can model evolution of far-from-equilibrium plasma (isotropization) on the gravity side as formation and evolution of a BH.
- Have to solve **nonlinear** Einstein's Equations $\rightarrow$ need numerics.

Introduction

Motivation

QGP behaves as a strongly coupled system. RHIC has shown that it isotropizes very quickly. We do not know why!

Aim

Try to understand short isotropization time.

Roadmap to computations

- QCD is hard. Use toy model:
  $\mathcal{N} = 4$ SYM $\rightarrow$ AdS/CFT comes into play
- Can model evolution of far-from-equilibrium plasma (isotropization) on the gravity side as formation and evolution of a BH.
- Have to solve **nonlinear** Einstein's Equations $\rightarrow$ need numerics.
- Try to simplify the problem to make it more tractable.

Holographic model

Metric ansatz compatible with isotropization on the boundary and diffeomorphism and translation invariance in the bulk

Holographic model

Metric ansatz compatible with isotropization on the boundary and diffeomorphism and translation invariance in the bulk

BULK

$$ds^2 = -A(r,t)dt^2 + \Sigma(r,t)^2\left[e^{B(r,t)}d\vec{x}_\perp^2 + e^{-2B(r,t)}dx_\parallel^2\right] + 2dr\,dt$$

Holographic model

Metric ansatz compatible with isotropization on the boundary and diffeomorphism and translation invariance in the bulk

BULK

$$ds^2 = -A(r,t)dt^2 + \Sigma(r,t)^2 \left[e^{B(r,t)} d\vec{x}_\perp^2 + e^{-2B(r,t)} dx_\parallel^2 \right] + 2dr\, dt$$

Induces on the boundary the desired properties

Holographic model

Metric ansatz compatible with isotropization on the boundary and diffeomorphism and translation invariance in the bulk

BULK

$$ds^2 = -A(r,t)dt^2 + \Sigma(r,t)^2\left[e^{B(r,t)}d\vec{x}_\perp^2 + e^{-2B(r,t)}dx_\parallel^2\right] + 2dr\,dt$$

Induces on the boundary the desired properties

BOUNDARY

$$ds^2 = -dt^2 + e^{B_0(t)}d\vec{x}_\perp^2 + e^{-2B_0(t)}dx_\parallel^2$$

Holographic model

Metric ansatz compatible with isotropization on the boundary and diffeomorphism and translation invariance in the bulk

BULK

$$ds^2 = -A(r,t)dt^2 + \Sigma(r,t)^2 \left[e^{B(r,t)} d\vec{x}_\perp^2 + e^{-2B(r,t)} dx_\parallel^2 \right] + 2dr\, dt$$

Induces on the boundary the desired properties

BOUNDARY

$$ds^2 = -dt^2 + e^{B_0(t)} d\vec{x}_\perp^2 + e^{-2B_0(t)} dx_\parallel^2$$

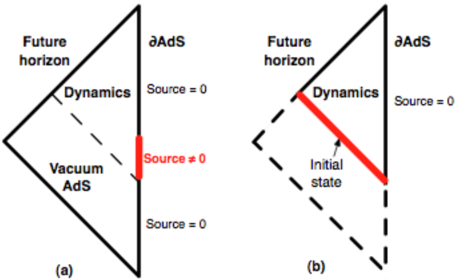
$\Rightarrow$ Time dependence of background fields induces anisotropy!

Numerics

Use spectral methods: Boundary conditions + specify initial $B_0(t)$ (source) and evolve using EEQs step by step (in time) and order by order (in r).

Numerics

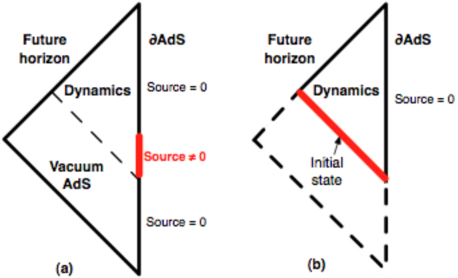
Use spectral methods: Boundary conditions + specify initial $B_0(t)$ (source) and evolve using EEQs step by step (in time) and order by order (in r).



(from 1202.0981)

Numerics

Use spectral methods: Boundary conditions + specify initial $B_0(t)$ (source) and evolve using EEQs step by step (in time) and order by order (in r).



(from 1202.0981)

Linearity simplifies computations → opens the door to more complicated settings.