Grupo de Teoría del Campo y Física Matemática

CγFM

Departamento de Física
Facultad de Ciencias, UNAM

Increase of the Energy Necessary to Probe Ultraviolet Theories Due to the Presence of a Strong Magnetic Field

Rodolfo Martínez, Leonardo Patiño and Tíber Urrutia

Introduction

Introduction

What we do?

We use the gauge gravity correspondence to study the renormalization group flow of a double trace non charged fermionic operator in a quark-gluon plasma subject to the influence of a strong magnetic field and compare it with the results for the case at zero temperature and no magnetic field, where the flow between two fixed points is observed.

Introduction

What we do?
We use the gauge gravity correspondence to study the renormalization group flow of a double trace non charged fermionic operator in a quark-gluon plasma subject to the influence of a strong magnetic field and compare it with the results for the case at zero temperature and no magnetic field, where the flow between two fixed points is observed.

The holographic renormalization program has been part of the gauge/gravity correspondence almost since its origins, and in particular the Wilsonian approach within this program has been the object of much attention in recent years [Heemskerk, Faulkner, K. Skenderis]. This approach provides a systematic framework to treat the properties of the renormalization flow in a gauge theory at a non-perturbative level by means of calculations in a dual gravitational theory.

Introduction

$\mathrm{AdS}^5 \times \mathrm{S}_5$ $\mathcal{N} = 4$

$SU(N)$

Introduction

The starting point is the AdS/CFT correspondence which provides a duality between type IIB string theory in and $\mathrm{AdS}^5 \times \mathrm{S}_5$ and a $\mathcal{N} = 4$ supersymmetric conformal $SU(N)$ field theory in a four dimensional Minkowski space.

Introduction

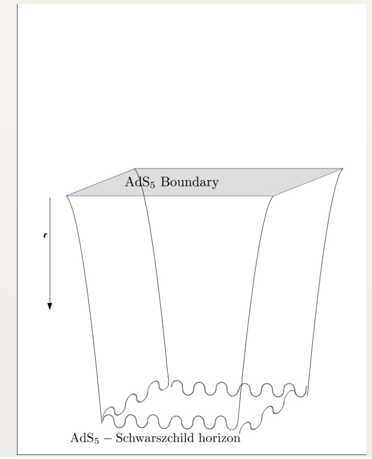
The starting point is the AdS/CFT correspondence which provides a duality between type IIB string theory in and $\mathrm{AdS}^5 \times \mathrm{S}_5$ and a $\mathcal{N}=4$ supersymmetric conformal $SU(N)$ field theory in a four dimensional Minkowski space.

This original correspondence has been modified in a number of ways, for instance by allowing the AdS^5 part of the geometry to have an horizon, becoming an AdS-Schwarzschild solution, which corresponds to the introduction of a finite temperature in the gauge theory.

Introduction

The starting point is the AdS/CFT correspondence which provides a duality between type IIB string theory in and $\mathrm{AdS}^5 \times \mathrm{S}_5$ and a $\mathcal{N} = 4$ supersymmetric conformal $SU(N)$ field theory in a four dimensional Minkowski space.

This original correspondence has been modified in a number of ways, for instance by allowing the AdS^5 part of the geometry to have an horizon, becoming an AdS-Schwarzschild solution, which corresponds to the introduction of a finite temperature in the gauge theory.



Introduction

Introduction

In general these modifications are admissible as long as a five dimensional subspace still approaches asymptotically AdS space close to its boundary, and the remaining compact subspace retains enough symmetry to describe the dual gauge theory. In all these constructions, the directions along the compact manifold are dual to internal degrees of freedom in the gauge theory, while the directions along the boundary of the asymptotic AdS are in correspondence with the directions in which the dual theory propagates.

Introduction

In general these modifications are admissible as long as a five dimensional subspace still approaches asymptotically AdS space close to its boundary, and the remaining compact subspace retains enough symmetry to describe the dual gauge theory. In all these constructions, the directions along the compact manifold are dual to internal degrees of freedom in the gauge theory, while the directions along the boundary of the asymptotic AdS are in correspondence with the directions in which the dual theory propagates.

Of particular importance to the renormalization program is that the direction that extends away from the boundary in to the bulk of the asymptotic AdS space, that is, the radial direction of this space, is related to the energy scale in the gauge theory.

Introduction

Introduction

$$r \Longleftrightarrow E$$

Introduction

$$r \Longleftrightarrow E$$

Since the gauge/gravity correspondence relates the **high energy behavior of the field theory with the low energy regime of the string theory,** to study high energy processes in the field theory, we can approximate its dual to be governed by the low energy limit of type IIB string theory, that is, type IIB supergravity,

Introduction

$$r \Longleftrightarrow E$$

Since the gauge/gravity correspondence relates the **high energy behavior of the field theory with the low energy regime of the string theory,** to study high energy processes in the field theory, we can approximate its dual to be governed by the low energy limit of type IIB string theory, that is, type IIB supergravity,

$$Z_{\text{Sugra}} = \int \mathcal{D}\Phi e^{-S[\Phi]} \sim \langle e^{-\int_{\partial AdS} \phi_0 \hat{O}} \rangle$$

Introduction

Introduction

Operators in the field theory side are related to fields in the gravity component of the correspondence. One general approach to finding this field is by determining the one that matches **the symmetries of the operator**.

Introduction

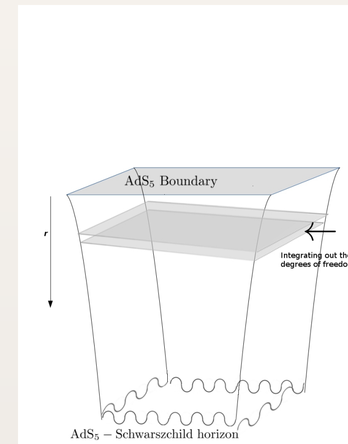
Operators in the field theory side are related to fields in the gravity component of the correspondence. One general approach to finding this field is by determining the one that matches **the symmetries of the operator**.

Two theories being dual implies that all the degrees of freedom of one of them have to be codified in the other and vise versa. Holografic renormalization implies that this should also be true for the renormalization of the fields in the gauge theory. In particular, a fraction of the space very near to the boundary is integrated out and written as a surface term.

Introduction

Operators in the field theory side are related to fields in the gravity component of the correspondence. One general approach to finding this field is by determining the one that matches **the symmetries of the operator**.

Two theories being dual implies that all the degrees of freedom of one of them have to be codified in the other and vise versa. Holografic renormalization implies that this should also be true for the renormalization of the fields in the gauge theory. In particular, a fraction of the space very near to the boundary is integrated out and written as a surface term.



The bulk equations

The bulk equations

In this section we study a fermionic field in a five dimensional asymptotically AdS background with a constant magnetic field, [D'Hoker, 2009] turned on. The metric takes the form

The bulk equations

In this section we study a fermionic field in a five dimensional asymptotically AdS background with a constant magnetic field, [D'Hoker, 2009] $F = B dx \wedge dy$ turned on. The metric takes the form

The bulk equations

In this section we study a fermionic field in a five dimensional asymptotically AdS background with a constant magnetic field, [D'Hoker, 2009] $F = B dx \wedge dy$ turned on. The metric takes the form

$$ds_5^2 = -U(r)dt^2 + V(r)\left(dx^2 + dy^2\right) + W(r)dz^2 + \frac{dr^2}{U(r)},$$

The bulk equations

In this section we study a fermionic field in a five dimensional asymptotically AdS background with a constant magnetic field, [D'Hoker, 2009] $F = B dx \wedge dy$ turned on. The metric takes the form

$$ds_5^2 = -U(r)dt^2 + V(r)\left(dx^2 + dy^2\right) + W(r)dz^2 + \frac{dr^2}{U(r)},$$

The background has to be constructed numerically, with a horizon located at $r=r_h$ and characterized by one single parameter b that measures the intensity of the magnetic field. As the magnetic field vanishes, the solution approaches the brane solution.

The bulk equations

In this section we study a fermionic field in a five dimensional asymptotically AdS background with a constant magnetic field, [D'Hoker, 2009] $F = B dx \wedge dy$ turned on. The metric takes the form

$$ds_5^2 = -U(r)dt^2 + V(r)\left(dx^2 + dy^2\right) + W(r)dz^2 + \frac{dr^2}{U(r)},$$

The background has to be constructed numerically, with a horizon located at $r=r_h$ and characterized by one single parameter b that measures the intensity of the magnetic field. As the magnetic field vanishes, the solution approaches the brane solution.

$$U_{BB}(r) = (r + \frac{r_h}{2})^2(1 - \frac{(\frac{3}{2}r_h)^4}{(r+\frac{r_h}{2})^4}),$$

$$V_{BB}(r) = \frac{4V_0}{9r_h^2}(r + \frac{r_h}{2})^2,$$

$$W_{BB}(r) = \frac{4}{3}(r + \frac{r_h}{2})^2,$$

The bulk equations

The bulk equations

For all elements of the family, except the one for *b=0*, the near horizon geometry is that of a **BTZ black hole** times a flat two dimensional space, given by inserting

The bulk equations

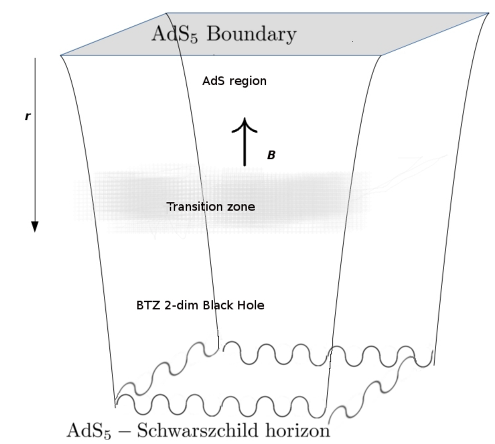
For all elements of the family, except the one for *b=0*, the near horizon geometry is that of a **BTZ black hole** times a flat two dimensional space, given by inserting

$$U_{BTZ}(r) = 3(r^2 - r_h^2), \quad V_{BTZ}(r) = \frac{B}{\sqrt{3}} \quad \text{and} \quad W_{BTZ}(r) = 3r^2,$$

The bulk equations

For all elements of the family, except the one for *b=0*, the near horizon geometry is that of a **BTZ black hole** times a flat two dimensional space, given by inserting

$$U_{BTZ}(r) = 3(r^2 - r_h^2), \quad V_{BTZ}(r) = \frac{B}{\sqrt{3}} \quad \text{and} \quad W_{BTZ}(r) = 3r^2,$$

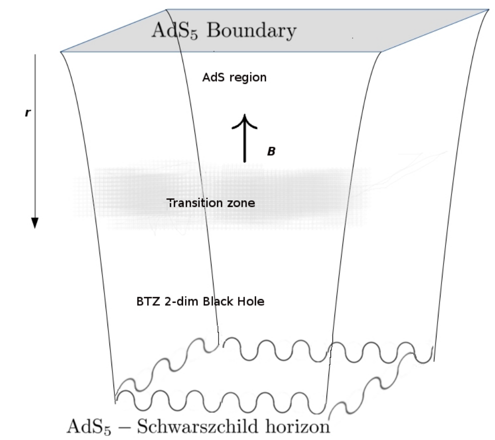


The bulk equations

For all elements of the family, except the one for *b=0*, the near horizon geometry is that of a **BTZ black hole** times a flat two dimensional space, given by inserting

$$U_{BTZ}(r) = 3(r^2 - r_h^2), \quad V_{BTZ}(r) = \frac{B}{\sqrt{3}} \quad \text{and} \quad W_{BTZ}(r) = 3r^2,$$

While the geometry close to the boundary is the asymptotic AdS_5 needed in the correspondence. As the intensity of the magnetic field increases, the transition from the near horizon geometry in to the AdS_5 zone **takes place at a larger radius**.



The Bulk equations

The Bulk equations

We now consider the action

The Bulk equations

We now consider the action

$$S = \int_{r=r_h}^{r=\frac{1}{\epsilon}} d^5x \sqrt{-g}\,\mathcal{L} + S_B[\psi, \bar{\psi}, \epsilon],$$

The Bulk equations

We now consider the action

$$S = \int_{r=r_h}^{r=\frac{1}{\epsilon}} d^5x\sqrt{-g}\,\mathcal{L} + S_B[\psi, \bar{\psi}, \epsilon],$$

Where the Lagrangian density for the fermionic field in the five dimensional background is given by

The Bulk equations

We now consider the action

$$S = \int_{r=r_h}^{r=\frac{1}{\epsilon}} d^5x\sqrt{-g}\,\mathcal{L} + S_B[\psi, \bar{\psi}, \epsilon],$$

Where the Lagrangian density for the fermionic field in the five dimensional background is given by

$$\mathcal{L} = i\bar{\psi}\left[(1/2)\left(\Gamma^M \overrightarrow{D}_M - \overleftarrow{D}_M \Gamma^M\right) - m\right]\psi,$$

The Bulk equations

We now consider the action

$$S = \int_{r=r_h}^{r=\frac{1}{\epsilon}} d^5x \sqrt{-g}\, \mathcal{L} + S_B[\psi, \bar{\psi}, \epsilon],$$

Where the Lagrangian density for the fermionic field in the five dimensional background is given by

$$\mathcal{L} = i\bar{\psi}\left[(1/2)\left(\Gamma^M \overrightarrow{D}_M - \overleftarrow{D}_M \Gamma^M\right) - m\right]\psi,$$

S_B is a boundary term that will be the topic of discussion bellow. For this work, the psi will be considered to bare no charge to couple to the magnetic field so its minimal coupling to *A* will be left out, and yet we will see that there is interesting physics in this approach

The renormalization flow

The renormalization flow

To begin with the Wilsonian approach to renormalization we need to start by integrating out the high energy degrees of freedom. The Wilsonian approach to renormalization is translated to the gravity side by observing that physical quantities **should not depend on the position of the boundary**.

The renormalization flow

To begin with the Wilsonian approach to renormalization we need to start by integrating out the high energy degrees of freedom. The Wilsonian approach to renormalization is translated to the gravity side by observing that physical quantities **should not depend on the position of the boundary**.

$$\frac{dS}{d\epsilon} = \int_{\rho=\epsilon} d^d x \; \mathcal{H} + \frac{\partial S_B}{\partial \epsilon} = 0,$$

The renormalization flow

To begin with the Wilsonian approach to renormalization we need to start by integrating out the high energy degrees of freedom. The Wilsonian approach to renormalization is translated to the gravity side by observing that physical quantities **should not depend on the position of the boundary**.

$$\frac{dS}{d\epsilon} = \int_{\rho=\epsilon} d^d x \ \mathcal{H} + \frac{\partial S_B}{\partial \epsilon} = 0,$$

Which is the Hamilton-Jacobi equation dictating the flow of the boundary term, dual to the Callan-Zymanzyk equation. The hamiltonian in this equation is just the Legendre transformation of $\mathcal{L}$ in the radial direction.

The renormalization flow

To begin with the Wilsonian approach to renormalization we need to start by integrating out the high energy degrees of freedom. The Wilsonian approach to renormalization is translated to the gravity side by observing that physical quantities **should not depend on the position of the boundary**.

$$\frac{dS}{d\epsilon} = \int_{\rho=\epsilon} d^d x \; \mathcal{H} + \frac{\partial S_B}{\partial \epsilon} = 0,$$

Which is the Hamilton-Jacobi equation dictating the flow of the boundary term, dual to the Callan-Zymanzyk equation. The hamiltonian in this equation is just the Legendre transformation of $\mathcal{L}$ in the radial direction.

$$\mathcal{H} = -\frac{i}{2}\sqrt{-g}\left[E^{\mu}_{a}\bar{\psi}\left(2\gamma^a\partial_\mu + \frac{1}{4}\omega_{bc,\mu}\{\gamma^a,[\gamma^b,\gamma^c]\}\right)\right],$$

Deforming the theory

Deforming the theory

To construct the theory we turn on two fermionic fields instead of one. This is necessary to construct a Dirac dual spinor field, since we have only two degrees of freedom instead of four, due to the boundary conditions we must fulfill

Deforming the theory

To construct the theory we turn on two fermionic fields instead of one. This is necessary to construct a Dirac dual spinor field, since we have only two degrees of freedom instead of four, due to the boundary conditions we must fulfill

$$S_B = \frac{i}{2}\int_{\rho=\epsilon} d^dx\sqrt{-g_B}\left[f\left(\bar{\psi}\psi + \bar{\chi}\chi\right) + g\left(\bar{\psi}^{(c)}\chi + \bar{\chi}\psi^{(c)}\right)\right],$$

Deforming the theory

To construct the theory we turn on two fermionic fields instead of one. This is necessary to construct a Dirac dual spinor field, since we have only two degrees of freedom instead of four, due to the boundary conditions we must fulfill

$$S_B = \frac{i}{2}\int_{\rho=\epsilon} d^d x\sqrt{-g_B}\left[f\left(\bar{\psi}\psi+\bar{\chi}\chi\right)+g\left(\bar{\psi}^{(c)}\chi+\bar{\chi}\psi^{(c)}\right)\right],$$

For the variation principle to be well defined, in the sense that a solution to the equation of motion is guarantied to extremize the action, we need to cancel the boundary contribution of any variation. We will do this here by imposing the Neumann boundary conditions

Deforming the theory

To construct the theory we turn on two fermionic fields instead of one. This is necessary to construct a Dirac dual spinor field, since we have only two degrees of freedom instead of four, due to the boundary conditions we must fulfill

$$S_B = \frac{i}{2}\int_{\rho=\epsilon} d^dx\sqrt{-g_B}\left[f\left(\bar{\psi}\psi + \bar{\chi}\chi\right) + g\left(\bar{\psi}^{(c)}\chi + \bar{\chi}\psi^{(c)}\right)\right],$$

For the variation principle to be well defined, in the sense that a solution to the equation of motion is guarantied to extremize the action, we need to cancel the boundary contribution of any variation. We will do this here by imposing the Neumann boundary conditions

$$\Pi = \frac{\delta S_B}{\delta\bar{\psi}} \quad \text{and} \quad \bar{\Pi} = \frac{\delta S_B}{\delta\psi},$$

Deforming the theory

Deforming the theory

The considerations just made, make it so that the boundary term we added is dual to a double trace operator that breaks chirality, making it a likely candidate to model. The boundary conditions now read

Deforming the theory

The considerations just made, make it so that the boundary term we added is dual to a double trace operator that breaks chirality, making it a likely candidate to model. The boundary conditions now read

$$f^2 + g^2 = 1,$$

Deforming the theory

The considerations just made, make it so that the boundary term we added is dual to a double trace operator that breaks chirality, making it a likely candidate to model. The boundary conditions now read

$$f^2 + g^2 = 1,$$

This result is **independent of the metric,** and it will be so as long as the metric is diagonal and depends only on the radial coordinate, which are conditions satisfied in particular by pure AdS.

The RG flow.

The RG flow.

The beta functions satisfy

The RG flow.

The beta functions satisfy

$$-\sqrt{U}\,(\partial_r g) = 2mg\sqrt{1-g^2}.$$

The RG flow.

The beta functions satisfy

$$-\sqrt{U}\,(\partial_r g) = 2mg\sqrt{1-g^2}.$$

and

The RG flow.

The beta functions satisfy

$$-\sqrt{U}\,(\partial_r g) = 2mg\sqrt{1-g^2}.$$

and

$$\sqrt{U}\,(\partial_r f) = 2m\left(1-f^2\right)$$

The RG flow.

The beta functions satisfy

$$-\sqrt{U}\,(\partial_r g) = 2mg\sqrt{1-g^2}.$$

and

$$\sqrt{U}\,(\partial_r f) = 2m\left(1-f^2\right)$$

These equations are very similar to the pure AdS results. But here the warping factor of the metric act as an energy correction

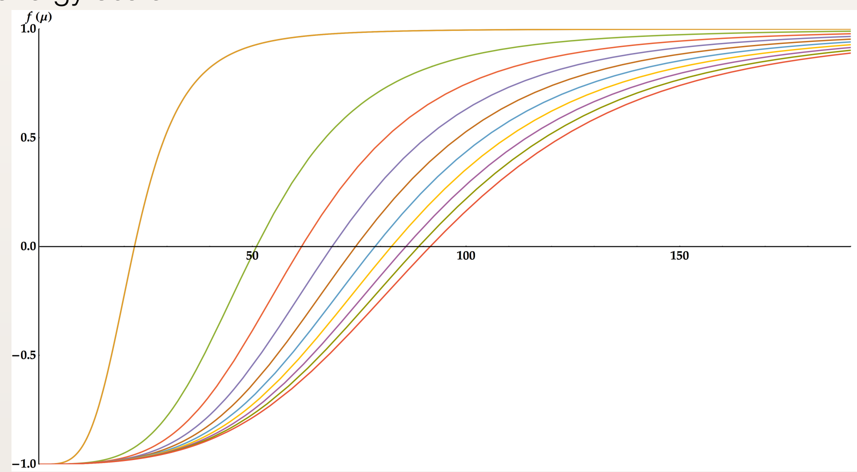
Results

Results

f as function of the energy scale for different values of b, where increasing values of b are further to the right, in particular the first plot on the left is the analytic result for the pure AdS case. All the plots share the same value for f at a particular infrared energy scale.

Results

f as function of the energy scale for different values of *b*, where increasing values of *b* are further to the right, in particular the first plot on the left is the analytic result for the pure AdS case. All the plots share the same value for *f* at a particular infrared energy scale.



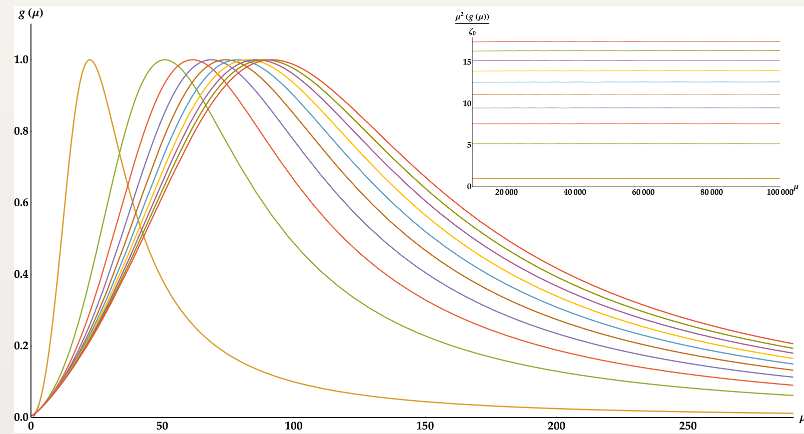
Results

Results

g as function of the energy scale, where increasing values of b are to the right. The first plot on the left is the analytic result for the pure AdS case. We show how for each value of b, g approaches a different constant that corresponds to the coupling of the gauge theory in the ultraviolet fixed point. All the plots share the same value for g at a particular infrared energy scale.

Results

g as function of the energy scale, where increasing values of b are to the right. The first plot on the left is the analytic result for the pure AdS case. We show how for each value of *b*, *g* approaches a different constant that corresponds to the coupling of the gauge theory in the ultraviolet fixed point. All the plots share the same value for *g* at a particular infrared energy scale.



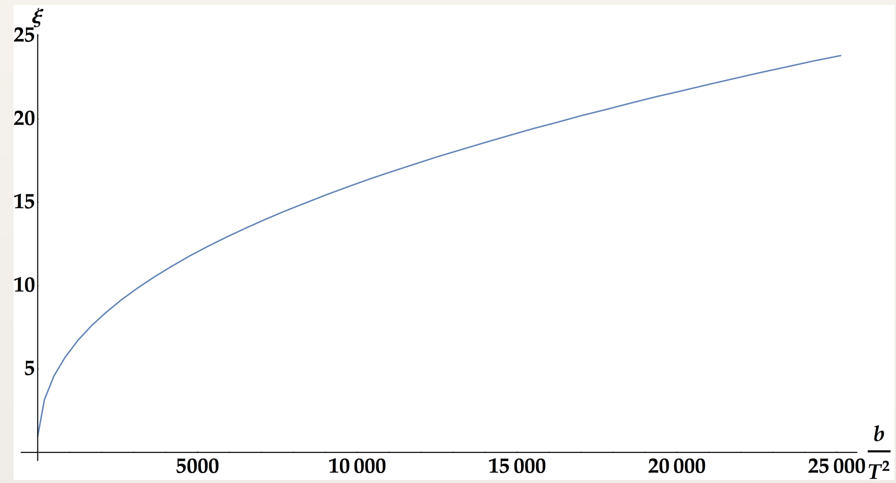
Results

Results

The coupling constant of the gauge theory in the ultraviolet fixed point as a function of the intensity of the magnetic field whit the value of g fixed to a constant at a particular infrared energy scale for all values of b.

Results

The coupling constant of the gauge theory in the ultraviolet fixed point as a function of the intensity of the magnetic field whit the value of g fixed to a constant at a particular infrared energy scale for all values of b.



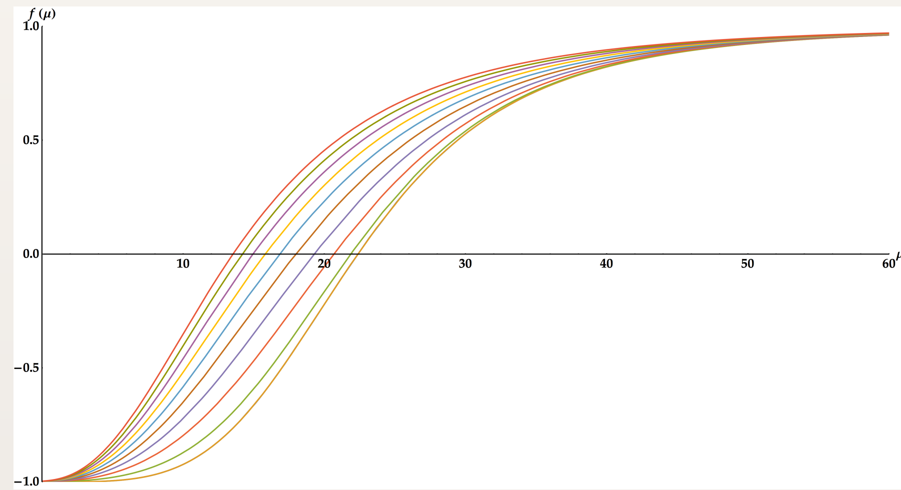
Results

Results

f as function of the energy scale, where increasing values of b are further to the left, in particular the first plot on the right is the analytic result for the pure AdS case. All the plots share the same value for f at a particular ultraviolet energy scale.

Results

f as function of the energy scale, where increasing values of *b* are further to the left, in particular the first plot on the right is the analytic result for the pure AdS case. All the plots share the same value for *f* at a particular ultraviolet energy scale.



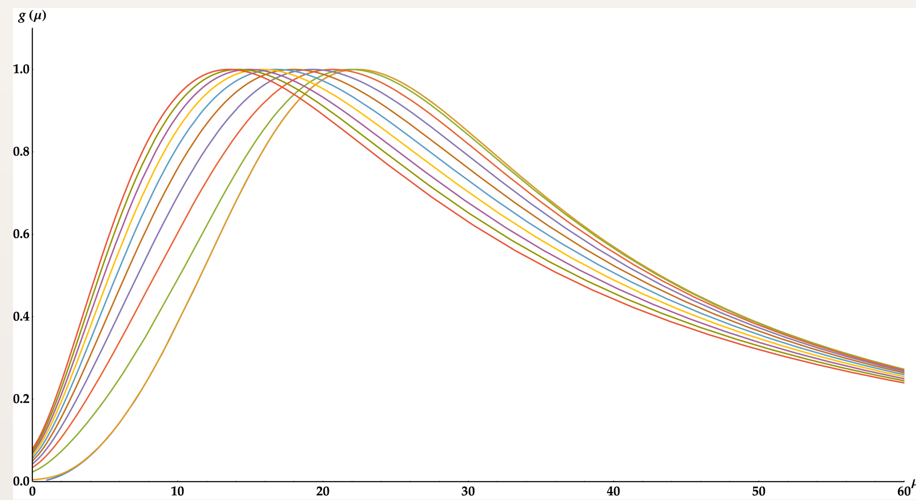
Results

Results

g as function of the energy scale, where increasing values of b are further to the left, in particular the first plot on the right is the analytic result for the pure AdS case. All the plots share the same value for g at a particular ultraviolet energy scale.

Results

g as function of the energy scale, where increasing values of *b* are further to the left, in particular the first plot on the right is the analytic result for the pure AdS case. All the plots share the same value for *g* at a particular ultraviolet energy scale.



Correlator

Correlator

The two point correlator confirm the dimensional reduction under an intense background magnetic field. This reduction has already been studied using the gauge/gravity correspondence, [D'Hoker]. It was shown how the operator algebra is projected to one of a lower dimensional theory. Also [Arean:2016] the drag force over a particle in directions perpendicular to the magnetic field, increases linearly and without a bound as the intensity of the field grows, while it stays bounded for propagation along the field.

Correlator

The two point correlator confirm the dimensional reduction under an intense background magnetic field. This reduction has already been studied using the gauge/gravity correspondence, [D'Hoker]. It was shown how the operator algebra is projected to one of a lower dimensional theory. Also [Arean:2016] the drag force over a particle in directions perpendicular to the magnetic field, increases linearly and without a bound as the intensity of the field grows, while it stays bounded for propagation along the field.

$$\lim_{r\to r_0} G(x^M - x_0^M) = \lim_{r\to r_0} e^{(F_0/2)(r-r_0)} G_{Flat}((x' - x_0')^\mu, r' - r_0'),$$

Correlator

The two point correlator confirm the dimensional reduction under an intense background magnetic field. This reduction has already been studied using the gauge/gravity correspondence, [D'Hoker]. It was shown how the operator algebra is projected to one of a lower dimensional theory. Also [Arean:2016] the drag force over a particle in directions perpendicular to the magnetic field, increases linearly and without a bound as the intensity of the field grows, while it stays bounded for propagation along the field.

$$\lim_{r\to r_0} G(x^M - x_0^M) = \lim_{r\to r_0} e^{(F_0/2)(r-r_0)} G_{Flat}((x' - x_0')^\mu, r' - r_0'),$$

With

Correlator

The two point correlator confirm the dimensional reduction under an intense background magnetic field. This reduction has already been studied using the gauge/gravity correspondence, [D'Hoker]. It was shown how the operator algebra is projected to one of a lower dimensional theory. Also [Arean:2016] the drag force over a particle in directions perpendicular to the magnetic field, increases linearly and without a bound as the intensity of the field grows, while it stays bounded for propagation along the field.

$$\lim_{r\to r_0} G(x^M - x_0^M) = \lim_{r\to r_0} e^{(F_0/2)(r-r_0)} G_{Flat}((x' - x_0')^\mu, r' - r_0'),$$

With

$$((x' - x_0')^\mu, r' - r_0') = (U_0^{1/2}(t - t_0), V_0^{1/2}(x - x_0), V_0^{1/2}(y - y_0), W_0^{1/2}(z - z_0), U_0^{-1/2}(r - r_0)),$$

Correlator

The two point correlator confirm the dimensional reduction under an intense background magnetic field. This reduction has already been studied using the gauge/gravity correspondence, [D'Hoker]. It was shown how the operator algebra is projected to one of a lower dimensional theory. Also [Arean:2016] the drag force over a particle in directions perpendicular to the magnetic field, increases linearly and without a bound as the intensity of the field grows, while it stays bounded for propagation along the field.

$$\lim_{r\to r_0} G(x^M - x_0^M) = \lim_{r\to r_0} e^{(F_0/2)(r-r_0)} G_{Flat}((x' - x_0')^\mu, r' - r_0'),$$

With

$$((x' - x_0')^\mu, r' - r_0') = (U_0^{1/2}(t - t_0), V_0^{1/2}(x - x_0), V_0^{1/2}(y - y_0), W_0^{1/2}(z - z_0), U_0^{-1/2}(r - r_0)),$$

and

Correlator

The two point correlator confirm the dimensional reduction under an intense background magnetic field. This reduction has already been studied using the gauge/gravity correspondence, [D'Hoker]. It was shown how the operator algebra is projected to one of a lower dimensional theory. Also [Arean:2016] the drag force over a particle in directions perpendicular to the magnetic field, increases linearly and without a bound as the intensity of the field grows, while it stays bounded for propagation along the field.

$$\lim_{r\to r_0} G(x^M - x_0^M) = \lim_{r\to r_0} e^{(F_0/2)(r-r_0)} G_{Flat}((x' - x_0')^\mu, r' - r_0'),$$

With

$$((x' - x_0')^\mu, r' - r_0') = (U_0^{1/2}(t - t_0), V_0^{1/2}(x - x_0), V_0^{1/2}(y - y_0), W_0^{1/2}(z - z_0), U_0^{-1/2}(r - r_0)),$$

and

$$F(r) \equiv -\frac{1}{2}\left(\frac{U'}{U} + 2\frac{V'}{V} + \frac{W'}{W}\right).$$

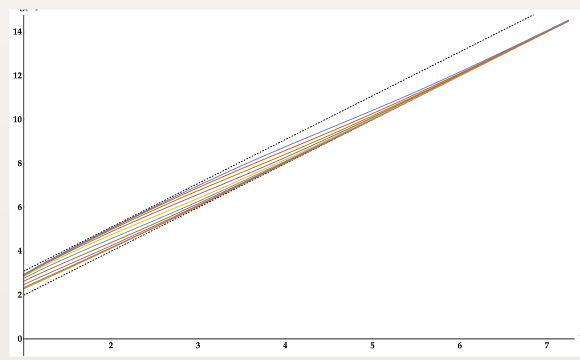
Correlator

Correlator

Logarithm of the metric functions vs. logarithm of *r*. *V* in the first plot shows how it starts as a large constant close to the horizon and it transitions in to going like *r*^2. W in the second plot shows how it starts as 3r^2, shown as one of the dotted lines, close to the horizon and it transitions in to going like *r*^2, shown as the other dotted line. U in the third plot shows how it starts in zero, behaves like 3*r*^2, shown as one of the dotted lines, for some intermediate values of *r* and then transitions in to going like *r*^2, shown as the other dotted line. The radius at which the transition happens for the three metric coefficients increases with the intensity of *b*.

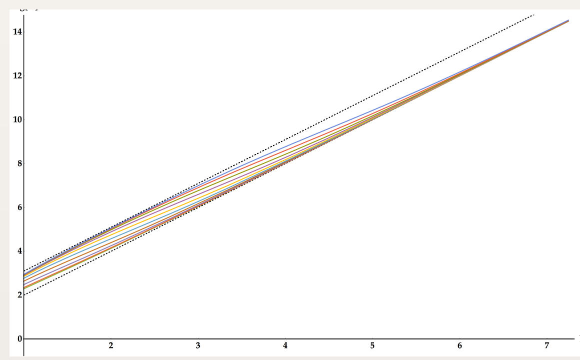
Correlator

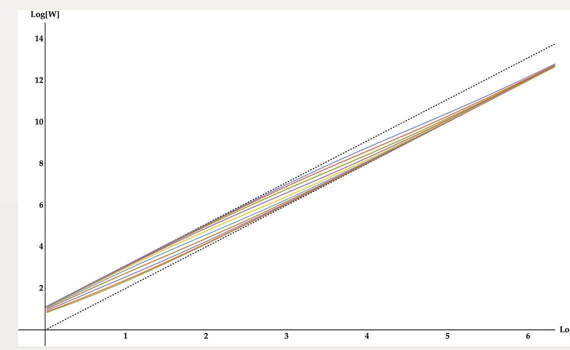
Logarithm of the metric functions vs. logarithm of *r*. *V* in the first plot shows how it starts as a large constant close to the horizon and it transitions in to going like *r*^2. W in the second plot shows how it starts as 3r^2, shown as one of the dotted lines, close to the horizon and it transitions in to going like *r*^2, shown as the other dotted line. U in the third plot shows how it starts in zero, behaves like 3*r*^2, shown as one of the dotted lines, for some intermediate values of *r* and then transitions in to going like *r*^2, shown as the other dotted line. The radius at which the transition happens for the three metric coefficients increases with the intensity of *b*.



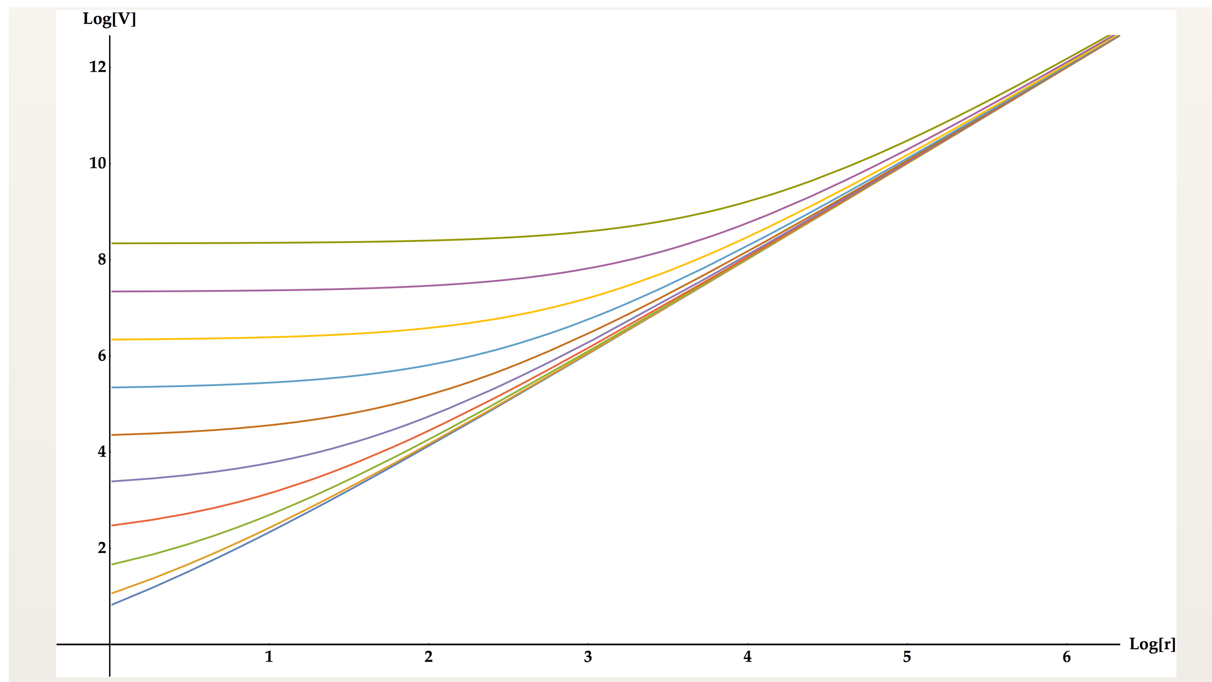
Correlator

Logarithm of the metric functions vs. logarithm of *r. V* in the first plot shows how it starts as a large constant close to the horizon and it transitions in to going like *r*^2. W in the second plot shows how it starts as 3r^2, shown as one of the dotted lines, close to the horizon and it transitions in to going like *r*^2, shown as the other dotted line. U in the third plot shows how it starts in zero, behaves like 3*r*^2, shown as one of the dotted lines, for some intermediate values of *r* and then transitions in to going like *r*^2, shown as the other dotted line. The radius at which the transition happens for the three metric coefficients increases with the intensity of *b*.





Correlator



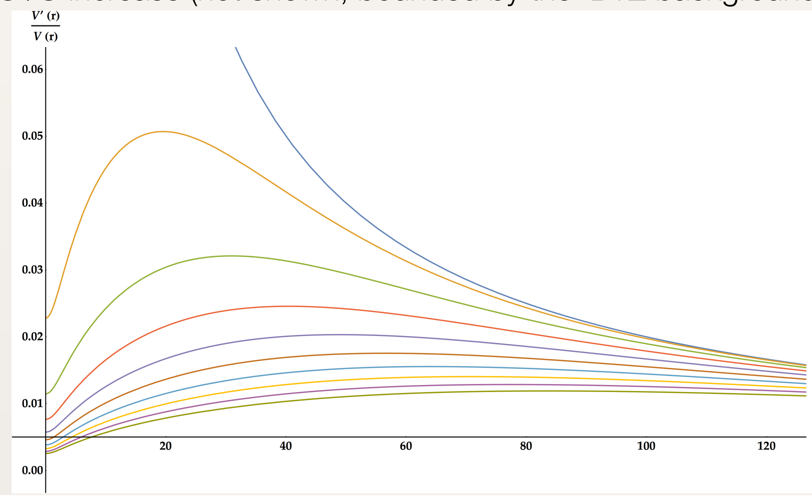
Correlator

Correlator

V'/V, as function of the energy scale. The highest line corresponds to the b=0 case and higher values of b show that we get as close to zero as desired, while W'/W and U'/U increase (not shown, bounded by the BTZ background).

Correlator

V'/V, as function of the energy scale. The highest line corresponds to the *b*=0 case and higher values of *b* show that we get as close to zero as desired, while W'/W and U'/U increase (not shown, bounded by the BTZ background).



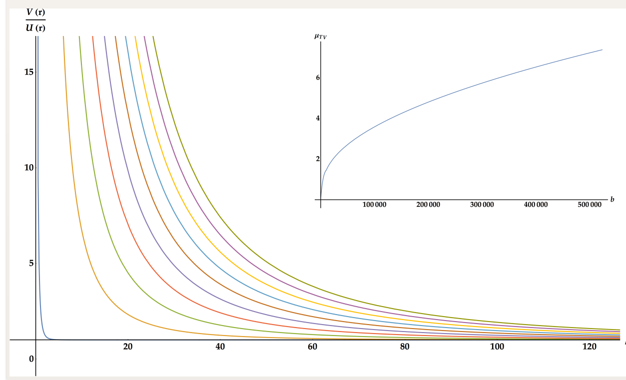
Correlator

Correlator

V/U and W/U as function of the energy. In the plot for V/U the lowest line corresponds to the b=0 case and higher values show that this ratio can be as high as desired. In the plot for W/U the lowest line again corresponds to b=0 and higher values shows a quickly convergence to the BTZ case. This plot shows the value of the energy scale at which the ratio W/U equals 1.1 for different values of b, and indicates that this energy scale quickly approaches a constant as b grows, so this ratio gets close to one for low energy scales regardless of the intensity of b.

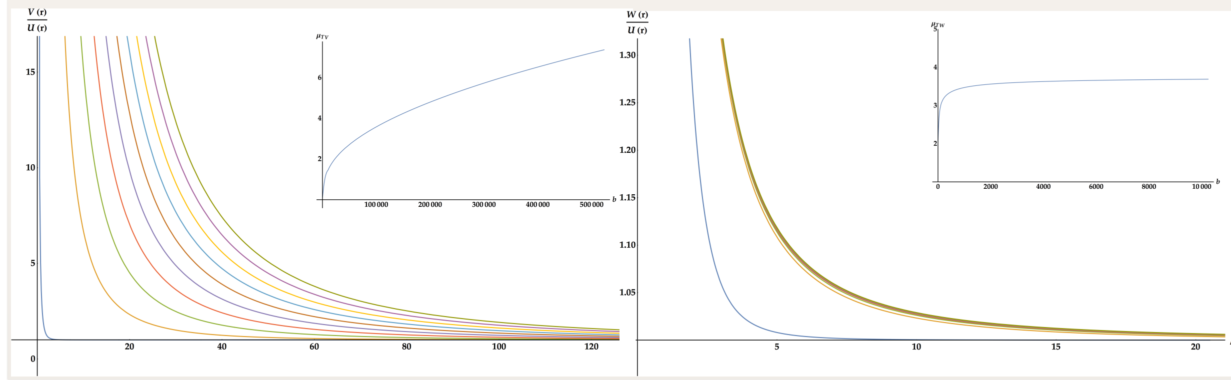
Correlator

V/U and *W/U* as function of the energy. In the plot for *V/U* the lowest line corresponds to the *b*=0 case and higher values show that this ratio can be as high as desired. In the plot for *W/U* the lowest line again corresponds to *b*=0 and higher values shows a quickly convergence to the BTZ case. This plot shows the value of the energy scale at which the ratio *W/U* equals 1.1 for different values of *b*, and indicates that this energy scale quickly approaches a constant as *b* grows, so this ratio gets close to one for low energy scales regardless of the intensity of *b*.



Correlator

V/U and *W/U* as function of the energy. In the plot for *V/U* the lowest line corresponds to the *b*=0 case and higher values show that this ratio can be as high as desired. In the plot for *W/U* the lowest line again corresponds to *b*=0 and higher values shows a quickly convergence to the BTZ case. This plot shows the value of the energy scale at which the ratio *W/U* equals 1.1 for different values of *b*, and indicates that this energy scale quickly approaches a constant as *b* grows, so this ratio gets close to one for low energy scales regardless of the intensity of *b*.



Conclusions

Conclusions

1) The separation of the theories in the energy scale is increased by the introduction of the background magnetic field and grows with its intensity.

Conclusions

1) The separation of the theories in the energy scale is increased by the introduction of the background magnetic field and grows with its intensity.

2) The difference in the coupling constant in the infrared and ultraviolet theories increases with the intensity of the field. So if fundamental physics are fixed at a very high energy scale, the apparent coupling that will be observed in a low energy experiment will depend on whether or not a magnetic field is affecting the theory.

Conclusions

1) The separation of the theories in the energy scale is increased by the introduction of the background magnetic field and grows with its intensity.

2) The difference in the coupling constant in the infrared and ultraviolet theories increases with the intensity of the field. So if fundamental physics are fixed at a very high energy scale, the apparent coupling that will be observed in a low energy experiment will depend on whether or not a magnetic field is affecting the theory.

3) From the computation of the correlator, we saw that the probability for propagation in directions perpendicular to the magnetic field vanish as the background field increases. This would imply that the detected ellipticity for a collision would receive an extra contribution from the non centrality through this mechanism, making it larger than anticipated if this is not taken in to account. This could be of particular relevance for experiments where measurements are used to determine the Fourier component vs of the azimuthal anisotropy.

Conclusions

Conclusions

Thank you