Nernst branes with Lifshitz asymptotics in N=2 gauged supergravity

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Introduction

Of current interest:

holographic description of non-relativistic field theories

`Kachru, Liu, Mulligan, 0808.1725`

Lifshitz field theories: invariant under Lifshitz scaling (anisotropy z)

$$t \longrightarrow \lambda^z \, t \quad , \quad x^i \longrightarrow \lambda \, x^i$$

A gravitational background with a Lifshitz scaling isometry:

$$ds^2 = -\frac{dt^2}{r^{2z}} + \delta^{ij} \, \frac{dx^i dx^j}{r^2} + \frac{dr^2}{r^2}$$

Isometry $r \rightarrow \lambda \, r \;, \; t \longrightarrow \lambda^z \, t \quad , \quad x^i \longrightarrow \lambda \, x^i$

Gravitational theories which allow for this background: for instance,

Einstein-Dilaton-Proca theories (i.e. massive Abelian vector field).

Introduction

Lifshitz spacetimes have divergent tidal forces at the center ($r = \infty$).
`Horowitz, Way, 1111.1243`

Cloaking by placing black object at center?

Investigate this in the context of $D = 4$, $N = 2$ gauged supergravity theories with arbitrary number of vector and hyper multiplets.

Gauging of isometries of quaternionic-Kähler manifold: generates effective Proca terms.

Question: flow from asymptotically Lifshitz spacetime to extremal black brane solution?

Focus on analytic flows.

First-order flow equations

Static solutions: line element

$$ds^2 = -e^{2U(r)}\, dt^2 + e^{2A(r)} \left(dr^2 + dx^2 + dy^2\right)$$

supported by

- vector multiplets (A^I_μ, Y^I):

$$E^I(r) \quad , \quad F^I_{xy} = p^I \quad , \quad Y^I(r) \quad , \quad I = 0, \ldots, n_V$$

- hyper multiplet scalars $q^\alpha(r)$, $\alpha = 1, \ldots, 4n_H$

Lagrangian encoded in: `Freedman, van Proeyen, Supergravity`

- prepotential $F(Y)$
- gauging of Abelian isometries $\mathcal{D}_\mu q^\alpha = \partial_\mu q^\alpha + k^\alpha_I\, A^I_\mu$,
  Killing vector field $k_I = k^\alpha_I \frac{\partial}{\partial q^\alpha}$
- potential $V(Y, q)$.

First-order flow equations

First-order rewriting of 1D effective Lagrangian:

$$L_{1D} = \sum (1\text{st})^2 + \Delta$$

- $\sum (1\text{st})^2$: first-order flow equations for $U(r), A(r), Y^I(r), q^\alpha(r)$
- $\delta\Delta = 0$: additional constraints, i.e. $P_I^1 = P_I^2 = 0$
  restricts flow to submanifold of quaternionic-Kähler manifold

First-order flow equations: susy/non-susy solutions.

Supersymmetric subset: BPS flow equations

`Halmagyi, Petrini, Zaffaroni, 1305.0730`

Lifshitz backgrounds with $z > 1$. No upper bound.
Constant scalars.

Specific model

STU prepotential: $F(Y) = -Y^1 Y^2 Y^3 / Y^0$

Universal hyper multiplet: $SU(2,1)/SU(2) \times U(1)$

Gauging of two if its Abelian isometries.

- Lifshitz background with $z = 2$, A_t^0
- $AdS_2 \times \mathbb{R}^2$ background

Constant scalars Y^I, q^α. Supported by different electric/magnetic charges. Interpolating solution unlikely.

Different mechanism: deform $z = 2$ Lifshitz background by $f = 1 \to f(r)$

$$ds^2 = -\frac{f(r)\, dt^2}{r^4} + \frac{dr^2 + dx^2 + dy^2}{r^2\, f(r)}$$

$$A_t^0 = \frac{f^2(r)}{r^2} \quad , \quad z^A = \frac{Y^A}{Y^0} = \frac{z_u^A}{f(r)} \quad , \quad q^\alpha = q_u^\alpha$$

Deforming $z = 2$

4D EOMs solved by two-parameter family of deformations

$$f^2(r) = \frac{r^2}{r^2 + \alpha\, r^4 + \beta} \quad , \quad \alpha, \beta \in \mathbb{R}$$

Does not satisfy first-order flow equations $\rightarrow$ not BPS.

Two cases:

- $\alpha \neq 0, \beta = 0$:

  interpolates between asymptotic $z = 2$ Lifshitz ($r \rightarrow 0$) and the near-horizon geometry of an extremal Nernst brane.

  `Barisch, Cardoso, Haack, Nampuri, Obers, 1108.0296`

  Hyperscale violating Lifshitz geometry with $(z, \theta) = (3, 1)$

$$ds^2 = r^{-(2-\theta)} \left(r^{-2(z-1)} dt^2 + dr^2 + dx^2 + dy^2 \right)$$

- $\alpha \neq 0, \beta \neq 0$: interpolates between conformal AdS and the near-horizon geometry of an extremal Nernst brane.

Deforming $z = 2$

Extremal Nernst brane: suffers from divergent scalars, $z^A \sim r \to \infty$

Regularize by heating it up

`Dempster, Errington, Mohaupt, 1501.07863`

Non-extremal Nernst brane in $U(1)$ gauged supergravity:

- entropy density $\mathcal{S} \sim T^{1/3}$ as $T \to 0$
- near-horizon geometry: hyperscale violating Lifshitz geometry with $(z, \theta) = (0, 2)$. Satisfies NEC.

Outlook:

analytic interpolating solution between $z = 2$ Lifshitz and non-extremal Nernst brane. Cloaking.

Thanks!