String theory duals of Lifshitz-Chern-Simons gauge theories

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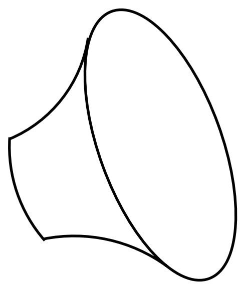
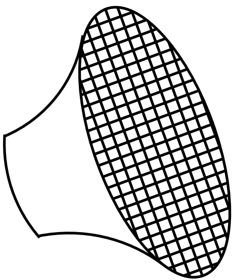
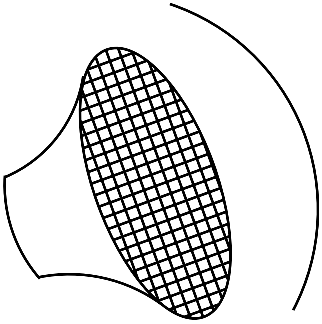
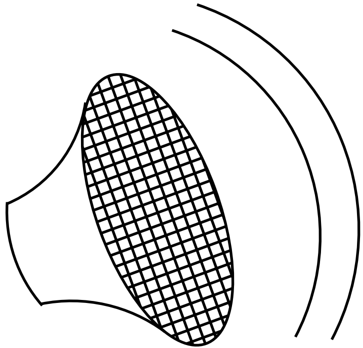
Based on arXiv:1111.0634[hep-th]









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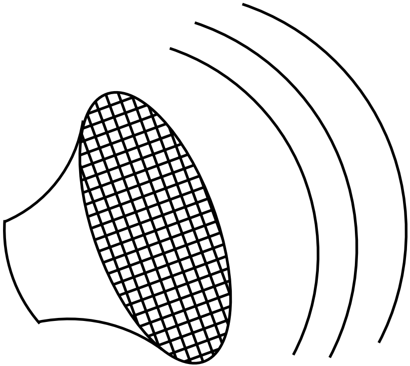

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Gravity in $AdS_5 \times S^5$ $\Longleftrightarrow$ $3+1$ D $\mathcal{N}=4$ SYM theory

Can we find examples of field theories that are holographically dual to gravity in Lifshitz spacetime?

Gravity in Lif^z_{d+1}"$\times$"$\mathcal{M}$ $\Longleftrightarrow$ $\boxed{?}_{z,d,\mathcal{M}}$

(1005.3291, 1008.2062, 1009.3445)

Examples of non-abelian Lifshitz gauge theories ($z=2$):

- $z=2$ Non-abelian Chern-Simons gauge theories studied by Kachru, Mulligan and Nayak (and generalizations of KMN).
- $z=2$ Non-abelian gauge theory studied by Hořava

No known FT (local) example for a generic value of z.

Claim #1: Non-Abelian LCS theories fit into the box.

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A confining solution with asymptotic $z = 2$ Lifshitz symmetry – dual to pure gauge theory. KK modes decouple from low energy dynamics. Somewhat unusual!

Holographic dictionary $\rightarrow$ arguments to support Claim # 1.

$2 + 1$ D $z = 2$ LCS theories (with or without adjoint matter) can be realized as deformations of $3 + 1$ D $\mathcal{N} = 4$ SYM theory.

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$$F_5 = 2L^4(1+\star)\Omega_5, \quad C_0 = \frac{Qx_3}{L_3}, \quad \Phi = \Phi_0. \quad \Gamma = \frac{Qe^{\Phi_0}}{2L_3}, \; x_3 \equiv x_3 + L_3.$$

1. Solves type IIB supergravity equations of motion.

2. Approaches $Lif^{d=2}_{z=2}$ as $r \longrightarrow 0$ and ends at $r = r_\star = r_0^2\Gamma$.

3. Regular... No conical singularity at $r_\star$! Fermions satisfy APBC around x_3. What determines r_0?

4. r_0 is related to a parameter specifying boundary conditions on the metric! hep-th/990215

Confinement scale and KK scale can be made arbitrarily different!

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Identification of the dual field theory

Conformal boundary: $ds^2 = 2dx_3dt + d\vec{x}^2$. Boundary theory is a deformation of DLCQ $\mathcal{N} = 4$ SYM theory.

RR-axion $(C_0) \iff \theta-$angle of $\mathcal{N} = 4$ theory.

$$\int \theta Tr\,(F \wedge F) = \int d\theta \wedge \left(A \wedge dA + \frac{2}{3} A \wedge A \wedge A\right)$$

$$= \frac{Q}{L_3} \int dx_3 \wedge \left(A \wedge dA + \frac{2}{3} A \wedge A \wedge A\right)$$

Reducing along x_3

$$\rightarrow Q \int \left(A \wedge dA + \frac{2}{3} A \wedge A \wedge A\right) \qquad \text{Chern-Simons term}$$

Asymptotic metric is invariant under $t \longrightarrow \lambda^2 t,\ \vec{x} \longrightarrow \lambda \vec{x} \Rightarrow$ dual field theory has $z = 2$ scale invariance.

Dual FT is a Lifshitz gauge theory with CS term.

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$$ds_5^2 = L^2 \left(\frac{2dx_3 dt + d\vec{x}^2 + dr^2}{r^2} + \frac{Q^2 e^{2\Phi_0}}{4L_3^2} dx_3^2 + ds_{\Omega^5}^2 \right)$$

We can identify operators dual to bulk deformations according to scaling dimension. Supersymmetry to the rescue! S^5-Sidekick!

Operators that are irrelevant in the relativistic theory can become marginal in the DLCQ theory.

$E_i = F_{3i}$ appears as an auxiliary field in the DLCQ theory and $[E_i]_{DLCQ} = 1 \Rightarrow$Terms like $\mathrm{tr}\left(F_{3i}F_{3i}F_{3j}F_{3j}\right)$ cannot be ignored.

We can ignore operators with dimensions greater than 8 ($z = 1$ counting). Irrelevant w.r.t both $z = 1$ and $z = 2$ counting.

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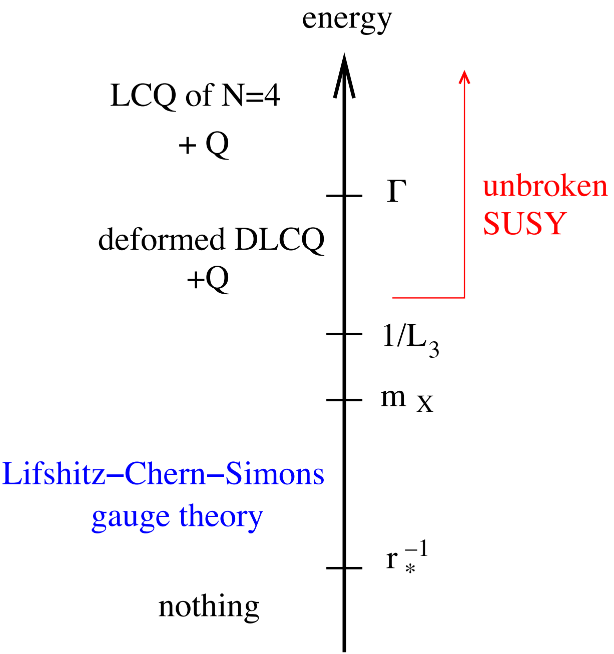
energy
LCQ of N=4
+ Q
Γ
unbroken
SUSY
deformed DLCQ
+Q
1/L3
m X
Lifshitz−Chern−Simons
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r*−1
nothing

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Dilatational mode of $S^5 \iff \mathcal{O}_8$

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In terms of these new variables

$$S_{3+1} \equiv \int dtd^2xdx_3\Bigg[\frac{1}{2{g'}_1^2}\text{tr}\,(E_iD_tA_i + A_tD_iE_i) + \frac{1}{4g_2^2}\text{tr}\left(F_{ij}F^{ij}\right) + \frac{1}{2g_3^2}\text{tr}\left(E_3^2\right) +$$

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At Last!

We will make the scalars and fermions massive. Let us compactify x_3 with APBC on fermions. Fermion mass $\sim L_3^{-1}$. Scalar mass $= m_X$. Interested in the low energy effective theory for $E < m_X, L_3^{-1}$.

KK reduction of the last term in S_{3+1} induces a CS term.

No Fermion zero modes. Scalar zero modes lifted by the mass deformation $\mathrm{tr}\left(X^2\right)$.

Scalar mass deformation dual to an excited string state. Effect felt through non-trivial boundary conditions on SUGRA fields. This determines r_0.[hep-th/990215] NOT PRECISE!

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$$S_{2+1} = \int dt d^2x \left[\frac{1}{2g_1'} \mathrm{tr} \left(\tilde{E}_i D_t \tilde{A}_i + \tilde{A}_t D_i \tilde{E}_i \right) + \frac{1}{4g'^2} \mathrm{tr} \left(\tilde{F}_{ij} \tilde{F}^{ij} \right) + \lambda_1' \mathrm{tr} \left([\tilde{E}_i, \tilde{E}_j]^2 \right) + \right.$$

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$$+ \text{irrelevant terms}$$

$\tilde{E}_3$ decouples...Irrelevant terms and $\sim$ can be dropped

Kachru, Mulligan, Nayak (to appear)

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Thank you!