Strong coupling dynamics of 3d SCFT

(focal subject: M2-branes & AdS/CFT)

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References: 1995 - early 2000

- Branes & 3d QFT: Hanany, Witten (1996.07); Seiberg, Witten (1997.11);
- Mirror symmetry: Intriligator, Seiberg ('96); de Boer, Hori, Ooguri, Oz, Yin ('96); Aharony, Hanany, Intriligator, Seiberg, Strassler ('97); more…
- Seiberg-like dualities: Aharony ('97);
- Monopole operators: Borokhov, Kapustin, Wu ('02);

2004 -

Superconformal Chern-Simons-matter theories (& M2-branes)

Schwarz (2004) ; Gaiotto, Yin (2007); Bagger, Lambert (2007); Gustavsson (2007); Aharony, Bergman, Jafferis, Maldacena (2008); Hosomichi-Lee-Lee-Lee-Park (2008);

2009 -

Studies of 3d strongly-coupled QFT (SCFT)

- S.K. (2009)
- Kapustin, Willett, Yaakov (2009)
- Drukker, Marino, Putrov (2010); Herzog, Klebanov, Pufu, Tesileanu (2010); …
- Jafferis (2010);
- Imamura, Yokoyama (2011);

2011-

More 3d theories and dualities: Dimofte, Gaiotto, Gukov; Cecotti, Cordova, Vafa; & more……

Motivation

- 4 dimensional SUSY QFT:

- phenomenological interest (4d N=1 SUSY)
- solvable models related to a more challenging QFT (e.g. QCD vs. SUSY QCD)
- connection to mathematics (including $\mathcal{N} \geq 2$ SUSY)

- 4d superconformal field theories (SCFT):

- Often appears as fixed points of SUSY QFT
- AdS/CFT: can study quantum gravity from QFT & vice versa

Motivation

- Why 3d (S)CFT?

- lower dimensional systems & critical phenomena
- some could be experimentally accessible.
- 3d SCFT: well controlled models in which we can learn about many issues in 3d
- rich mathematical structures
- M2 branes, AdS_4/CFT_3 & more…

- In a way, 3d systems are easier.
- On the other hand, more challenging… (many 4d SCFT techniques)
- studies with string theory motivation: from mid 90's (branes, SUSY)

Some properties of 3d gauge theories

- $[g_{YM}^2]$ ~ mass: free in UV, but generically strongly-coupled in IR
- Nontrivial IR dynamics: cannot have “simple” theories like 4d N=4 SYM.
- 4d gauge theories sometimes have marginal gauge couplings: free theories give quantities protected by superconformal symmetry

- Anomalies in 4d are often very useful, good notion of central charges.
- These do not have obvious analogues in 3d.

- Refined usage of SUSY (localization): **subject of these lectures**
- Objects: superconformal index, 3-sphere partition function, & more…?

Some properties of 3d gauge theories

- 3d gauge theories can have nonzero Chern-Simons couplings

$$\frac{k}{4\pi}\int \mathrm{tr}\left(AdA - \frac{2i}{3}A^3\right) = \frac{k}{4\pi}\int d^3x\ \mathrm{tr}\left(\epsilon^{\mu\nu\rho}A_\mu\partial_\nu A_\rho - \frac{2i}{3}A_\mu A_\nu A_\rho\right)$$

- massive gauge fields: $-\frac{1}{4g^2}F_{\mu\nu}F^{\mu\nu} + \frac{k}{4\pi}\epsilon^{\mu\nu\rho}A_\mu\partial_\nu A_\rho : \quad 0 = \partial_\mu F^{\mu\nu} + \frac{kg^2}{2\pi}\epsilon^{\nu\alpha\beta}\partial_\alpha A_\beta$

$$0 = -p_\mu p^\mu A^\nu + p_\mu p^\nu A^\mu + \frac{ikg^2}{2\pi}\epsilon^{\nu\alpha\beta}p_\nu A_\rho \rightarrow\ p_\mu A^\mu = 0 :\ 0 = \left(-p_\mu p^\mu \eta^{\alpha\beta} - \frac{ikg^2}{2\pi}p_\mu\epsilon^{\mu\alpha\beta}\right)A_\beta = 0$$

$$0 = m^2\delta^{ab} + i\frac{kg^2}{2\pi}m\epsilon^{ab} \sim m^2\mathbf{1} - \frac{kg^2}{2\pi}m\sigma_2 \rightarrow\ m = \frac{kg^2}{2\pi}\ ,\quad \sigma_2 = \mathrm{sgn}(k)$$

- "integrating out" gauge fields, Lagrangian description (of SCFT)

- The CS level k also controls (gauge) interactions

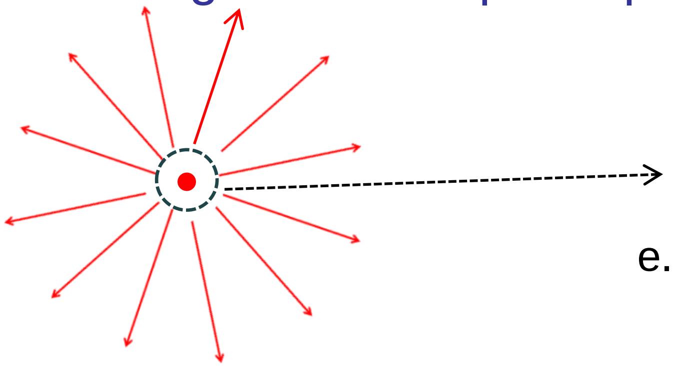
coupling constant

$$\hat{A}_\mu \equiv \sqrt{k}A_\mu\ ,\quad D_\mu = \partial_\mu - iA_\mu = \partial_\mu - \boxed{\frac{i}{\sqrt{k}}}\hat{A}_\mu$$

- Also, CS term makes the phases of 3d theories more nontrivial than 4d

Some properties of 3d gauge theories

- Local operators which cannot be written in a simple way with elementary fields: magnetic monopole operators (creating flux around a point)



$$\boxed{\int_{S^2} F = 2\pi H}$$

GNO charge
(Goddard, Nuyts, Olive)

e.g. $A = \frac{H}{2}(\pm 1 - \cos\theta d\phi)\ ,\quad H \in (\text{Cartan subalgebra})$

$\boxed{\exp(2\pi i H) = 1}\ ,\quad U(N):\ H = \text{diag}(n_1, n_2, \cdots, n_N)\quad n_i \in \mathbb{Z}$

- Similar to 't Hooft loop operator in 4d: local in 3d

- Sometimes they are responsible for symmetry enhancements

- Also provide a useful window to understand IR physics, & so on…

- Non-perturbative objects (from weakly coupled gauge theory viewpoint)

Recent progress on 3d SCFT

- Lagrangian description of some 3d SCFT: Chern-Simons-matter theories
- motivated by finding a better description for M2-branes
- This triggered concrete & technically sophisticated studies.
- BLG (2007), ABJM (2008)

- Progress on exactly calculable quantities at strong coupling
- superconformal index [S.K. (2009)]
- partition function on 3-sphere [Kapustin, Willett, Yaakov (2009)]
- probably more to come…

- With these tools, more refined properties explored.

Contents

1. motivation (main references)
2. aspects of 3d SCFT (today) [Schwarz (2004)][Gaiotto-Yin (2007)][ABJM (2008)]
3. superconformal index (2nd lecture) [S. Kim (2009)]
4. S^3 partition function (3rd lecture) [Kapustin-Willett-Yaakov (2009)]

3d SUSY gauge theories

- There are many classes of 3d SUSY QFT & many possible motivations.
- I will discuss generalities of classical SCFT in N=2 SUSY language, but main examples will preserve more SUSY (e.g. ABJM)

- N-extended SUSY: $Q^a_\alpha \quad (a = 1, 2, \cdots, \mathcal{N};\ \alpha = \pm)$

$$\{Q^a_\alpha, Q^b_\beta\} = \delta^{ab}(\gamma^\mu \epsilon)_{\alpha\beta} P_\mu + \delta^{ab}\epsilon_{\alpha\beta}(\text{possible central extension})$$

- R-symmetry $SO(\mathcal{N})$ rotating supercharges as vectors: may be broken in non-conformal theories (e.g. Fayet-Iliopoulos (FI) term, mass terms)
- R-symmetry will be part of the superconformal algebra in SCFT

3d gauge theories

- N=2 vector supermultiplets:

$$V = 2i\theta\bar{\theta}\sigma(x) + 2\theta\gamma^\mu\bar{\theta}A_\mu(x) + \sqrt{2}i\theta^2\bar{\theta}\bar{\lambda}(x) - \sqrt{2}i\bar{\theta}^2\theta\lambda(x) + \theta^2\bar{\theta}^2 D(x)$$

parity compatible with SUSY: $\sigma:\ \text{pseudoscalar},\ D:\ \text{scalar}$

- N=2 chiral supermultiplets: (any rep. of gauge group)

$$\Phi = \phi(y) + \sqrt{2}\theta\psi(y) + \theta^2 F(y) \quad (y^\mu = x^\mu + i\theta\gamma^\mu\bar{\theta})$$

- SUSY action:

$$S = \int d^3x \int d^4\theta \bar{\Phi} e^V \Phi + \int \frac{1}{g_{YM}^2}\Sigma^2 + \int d^2\theta W(\Phi) + c.c.\ ,\ \ \Sigma = \bar{D}^\alpha D_\alpha V\ \ (\text{Abelian})$$

- In components…

$$S_m = \int d^3x \left(-D_\mu\bar{\phi}D^\mu\phi - i\bar{\psi}\gamma^\mu D_\mu\psi - \bar{\phi}\sigma^2\phi + \bar{\phi}D\phi - i\bar{\psi}\sigma\psi + i\bar{\phi}\lambda\psi + i\bar{\psi}\bar{\lambda}\phi + |F|^2\right)$$

$$S_{YM} = \frac{1}{g_{YM}^2}\int d^3x \left(-\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{2}D_\mu\sigma D^\mu\sigma - i\bar{\lambda}\gamma^\mu D_\mu\lambda - i\bar{\lambda}[\sigma,\lambda] + \frac{1}{2}D^2\right)$$

N=4 (& N=3) multiplets

- Vector supermultiplets:

- N=2 vector $V = 2i\theta\bar{\theta}\sigma(x) + 2\theta\gamma^{\mu}\bar{\theta}A_{\mu}(x) + \sqrt{2}i\theta^2\bar{\theta}\bar{\lambda}(x) - \sqrt{2}i\bar{\theta}^2\theta\lambda(x) + \theta^2\bar{\theta}^2 D(x)$

- adjoint chiral $\Phi = \phi(y) + \sqrt{2}\theta\psi(y) + \theta^2 F(y) \quad (y^{\mu} = x^{\mu} + i\theta\gamma^{\mu}\bar{\theta})$

- hypermultiplets: pair of chirals in conjugate rep. $Q = q(y) + \sqrt{2}\theta\psi_q(y) + \theta^2 F_q(y)\,, \quad \tilde{Q}$

- SUSY action: To the N=2 YM & matter actions for all chiral fields, add…

$$\Delta S = \int d^3x \int d^2\theta\, \Phi Q\tilde{Q} = \int d^3x\, (F q\tilde{q} + \phi F_q \tilde{q} + \phi q F_{\tilde{q}} + \text{fermions})$$

$$D = D^3,\ F = \frac{D^1 + iD^2}{\sqrt{2}}\ ;\ SU(2)_R \text{ triplet}$$

$$\sigma = \phi^3,\ \phi = \frac{\phi^1 + i\phi^2}{\sqrt{2}}:\ SU(2)_L \text{ triplet}$$

$$q_a \equiv (q, \tilde{q}^{\dagger}):\ SU(2)_R \text{ doublet}$$

$$q^{\dagger} D q - \tilde{q} D \tilde{q}^{\dagger} \to\ 2q^{\dagger a} D^I (\tau^I)_a{}^b q_b$$

$$q^{\dagger}\sigma^2 q + \tilde{q}^{\dagger}\sigma^2\tilde{q} \to\ q^{\dagger}(\phi^i)^2 q + \tilde{q}(\phi^i)^2\tilde{q}^{\dagger}$$

3d superconformal field theories

- Some of these theories flow to nontrivial CFTs (at strong coupling).

$$P_\mu,\ J_{\mu\nu},\ Q^i_\alpha;\ D,\ K_\mu,\ S^i_\beta; R^{ij}$$

$$2\{Q^i_\alpha, S^{j\beta}\} = \delta^{ij}\delta^\beta_\alpha D + R^{ij}\delta^\beta_\alpha + \delta^{ij} J_\alpha{}^\beta$$

- Many SCFT's defined without Lagrangian descriptions w/ explicit IR symmetries: previous studies restricted to simple protected quantities like chiral operators, moduli spaces, superpotential, …

- Example: 3d N=8 U(N) SYM for N D2's, probe R^7 (or R^7 x S^1 in M-theory)

- At low energies, the circle probed by "dual photon" is large: M2-branes.
- Expects maximal superconformal symmetry: not obvious from QFT

Chern-Simons terms & Lagrangian SCFT

- Propagating degrees in the gauge fields can be integrated out
- Leaves interaction with CS gauge fields: strength controlled by 1/k
- SUSY CS action: (drop the SYM parts in the action)
- N=2: $$\mathcal{L}_{CS} = \frac{k}{4\pi}\mathrm{tr}\left(A \wedge dA - \frac{2i}{3}A^3 + \boxed{i\bar{\lambda}\lambda - 2D\sigma}\right)$$ may be algebraically integrated out
- N=3: Add $-\frac{k}{8\pi}\mathrm{tr}\Phi^2$ to superpotential $$\mathcal{L}_{CS} = \frac{k}{4\pi}\mathrm{tr}\left(AdA - \frac{2i}{3}A^3 + \boxed{i\bar{\lambda}\lambda + i\bar{\psi}\psi} - \boxed{2D^i\phi^i}\right)$$ combined to $i\bar{\lambda}_{a\dot{b}}\lambda^{a\dot{b}}$
  only diagonal of $SU(2)_L \times SU(2)_R$ is preserved
- No dimensionful coupling: classically superconformal
- N=2: exactly superconformal if superpotential is zero [Gaiotto-Yin (2007)]
- N=3: exactly superconformal

Chern-Simons terms & Lagrangian SCFT

- For YM-CS theories, no more than N=3 SUSY is possible.
- (Parity-breaking) N=3 vector supermultiplet: YM-CS theory

spin	$+1$	$+1/2$	0	$-1/2$
degeneracy	1	3	3	1

- A bound for Poincare SUSY (at least with above SUSY & general matter contents).
- N=3 or lower SCFT studied using this Poincare SUSY in UV & extending it: [Schwarz (2004)] [Gaiotto-Yin (2007)]
- IR theory can be more SUSY, with carefully chosen fields & action, more SUSY possible [Gaiotto-Witten] [Hosomichi-Lee-Lee-Park] [Aharony-Bergman-Jafferis-Maldacena] [Bagger-Lambert] [Gustavsson], …

Chern-Simons-matter QFT with more SUSY

- N=4 SUSY: [Gaiotto, Witten (Apr 2008)] [Hosomichi, Lee, Lee, Lee,Park (May 2008)]
- N=5 SUSY: [HLLLP (2008)] 0806.4977
- N=6 SUSY: [Aharony, Bergman, Jafferis, Maldacena (2008)] 0806.1218
- N=7: absent…
- N=8: for SU(2) x SU(2) gauge group [Bagger-Lambert] [Gustavsson] (2007)
- Also, N=6 ABJM proposed to be N=8 SCFT at CS level k=1, 2 (details later)

3d theories for M2/M5

- So far, I sketched how to "generate" (classical) SCFT's.
- Sometimes, we want to study particular CFTs for definite systems in string/M-theory: e.g. M2, M5 wrapped on 3-manifolds, b.c. of D3's …
- Today & in 2 more lectures, I will focus on SCFT's for M2-branes as an illustrating example of how to study strong-coupling 3d physics, but many techniques extend to other problems. (I will comment on some of them.)
- Especially, I will mostly consider "most supersymmetric" M2-brane theory: ABJM (in a sense)

ABJM Chern-Simons-matter theories

- M2-branes probing 8d cone geometry in M-theory
- 8d: $\boxed{\mathbb{R}^8,\ \mathbb{R}^8/\mathbb{Z}_2\ (\mathcal{N}=8)\ ;\ \ \mathbb{R}^8/\mathbb{Z}_k\ (k\geq 3:\ \mathcal{N}=6)}\,;\ \ \mathbb{R}^8/\Gamma\ (\mathcal{N}=5,4)\ ;$

$$C\,(\text{tri Sasakian})\ (\mathcal{N}=3)\,;\ \ C\,(\text{Sasaki Einstein})\ (\mathcal{N}=2)\,;\ \ C\,(\text{weak } G_2)\ (\mathcal{N}=1)$$

- In all cases, the 3d theory preserves parity if the transervse space does not have background fields breaking it (e.g. discrete torsions)

- ABJM (or BLG): use $U(N)_k$ x $U(N)_{-k}$ CS gauge fields, QFT parity associated with exchanging two gauge fields.

$$\frac{k}{4\pi}\int \mathrm{tr}\left(AdA-\frac{2i}{3}A^3\right)-\mathrm{tr}\left(\tilde{A}d\tilde{A}-\frac{2i}{3}\tilde{A}^3\right)$$

- Matters: representation should be invariant under this exchange.

$$\text{hypermultiplets in } (N,\bar{N})\ \stackrel{U(N)\leftrightarrow U(N)}{\longrightarrow}\ (\bar{N},N)\ \stackrel{\text{c.c.}}{\longrightarrow}\ (N,\bar{N})$$

ABJM Chern-Simons-matter theories

- Take 2 hypermultiplets in bi-fundamental rep. of U(N) x U(N).
- Action: (N=2 formalism… but N=3 SUSY can be made manifest)

$$\mathcal{L}_{CS} = \frac{k}{4\pi}\mathrm{tr}\left(A\wedge dA - \frac{2i}{3}A^3 + i\bar{\lambda}\lambda - 2D\sigma\right) - \frac{k}{4\pi}\mathrm{tr}\left(\tilde{A}\wedge d\tilde{A} - \frac{2i}{3}\tilde{A}^3 + i\bar{\tilde{\lambda}}\tilde{\lambda} - 2\tilde{D}\tilde{\sigma}\right)$$

$$\begin{aligned}\mathcal{L}_m \;=\; \mathrm{tr}\Big[& -D_\mu\bar{A}^a D^\mu A_a - D_\mu\bar{B}^{\dot{a}}D_\mu B_{\dot{a}} - i\bar{\psi}^a\gamma^\mu D_\mu\psi_a - i\bar{\chi}^{\dot{a}}\gamma^\mu D_\mu\chi_{\dot{a}} \\ & -(\sigma A_a - A_a\tilde{\sigma})\left(\bar{A}^a\sigma - \tilde{\sigma}\bar{A}^a\right) - (\tilde{\sigma}B_{\dot{a}} - B_{\dot{a}}\sigma)\left(\bar{B}^{\dot{a}}\tilde{\sigma} - \sigma\bar{B}^{\dot{a}}\right) \\ & +\bar{A}^a D A_a - A_a\tilde{D}\bar{A}^a - B_{\dot{a}}D\bar{B}^{\dot{a}} + \bar{B}^{\dot{a}}\tilde{D}B_{\dot{a}} \\ & -i\bar{\psi}^a\sigma\psi_a + i\psi_a\tilde{\sigma}\bar{\psi}^a + i\bar{A}^a\lambda\psi_a + i\bar{\psi}^a\bar{\lambda}A_a - i\psi_a\tilde{\lambda}\bar{A}^a - iA_a\bar{\tilde{\lambda}}\bar{\psi}^a \\ & +i\chi_{\dot{a}}\sigma\bar{\chi}^{\dot{a}} - i\bar{\chi}^{\dot{a}}\tilde{\sigma}\chi_{\dot{a}} - i\chi_{\dot{a}}\lambda\bar{B}^{\dot{a}} - iB_{\dot{a}}\bar{\lambda}\bar{\chi}^{\dot{a}} + i\bar{B}^{\dot{a}}\tilde{\lambda}\chi_{\dot{a}} + i\bar{\chi}^{\dot{a}}\bar{\tilde{\lambda}}B_{\dot{a}}\Big] + \mathcal{L}_{\mathrm{sup}}\end{aligned}$$

$$W = -\frac{2\pi}{k}\epsilon^{ab}\epsilon^{\dot{a}\dot{b}}\mathrm{tr}(A_a B_{\dot{a}} A_b B_{\dot{b}})$$

- Integrating out auxiliary fields, one finds that SU(2) R-symmetry enhances to SU(4) ~ SO(6): signals N=6 superconformal symmetry
- E.g. $SU(2)^2$ rotating A & B separately, not commuting with $SU(2)_R$
- N=6 SUSY explicitly shown shortly [HLLLP]

ABJM moduli space & SUSY

- Moduli space: R^8/Z_k , solve (potential) = 0: take all 4 scalars commute…

$$\sigma = \frac{2\pi}{k}\left(A_a \bar{A}^a - \bar{B}^{\dot{a}} B_{\dot{a}}\right) \;,\quad \tilde{\sigma} = \frac{2\pi}{k}\left(\bar{A}^a A_a - B_{\dot{a}} \bar{B}^{\dot{a}}\right) \quad \rightarrow \; \sigma = \tilde{\sigma}$$

$$\sigma A_a - A_a \tilde{\sigma} = 0, \; \tilde{\sigma} B_a - B_a \sigma = 0, \; \partial W = 0 \; \rightarrow \; V_{\mathrm{bosonic}} = 0$$ locally R^8

- Remaining gauge transformation makes it to $\mathbb{R}^8/\mathbb{Z}_k$ [ABJM]

- This result implies that SUSY could enhance to N=8 at k=1,2

- Note: This is not always a strong evidence. Exists counterexample…
- ABJM also provides brane realization: more reliable evidence

Challenges for strongly interacting ABJM

- Many strong-coupling issues: k=1 is in many ways most interesting (esp. from M-theory viewpoint)

- For example, verification of SUSY enhancement from QFT?
- Hard question, as it is supposed to arise only at k=1,2 (strong coupling)

- In 3d Chern-Simons-matter theories, symmetry enhancement often happens by having gauge invariant operators including monopole operators: **new conserved current operator**…

Monopole operators in 3 dimensional QFT

- Change b.c. around the insertion point ("magnetic type" operators)
- 3d YM gauge theories: demand singular b.c. $F \sim \star_3 d\left(\frac{1}{|x|}\right) H$
- More appropriate for our purpose: b.c. with quantized flux on S^2 surrounding the point $\int_{S^2} F = 2\pi H$ $\quad H = \mathrm{diag}(n_1, n_2, \cdots, n_N)$

  for U(N) gauge group
- The monopole operator breaks gauge symmetry to a subgroup.
- Magnetic charges (GNO charge): not physically meaningful themselves
- Topologically conserved current: CFT dual of M-theory KK momentum

$$j_\mu = \frac{1}{2}\epsilon_{\mu\nu\rho}\mathrm{tr}F^{\nu\rho} \;\rightarrow\; \mathrm{ABJM}:\; j_\mu = \frac{1}{2}\epsilon_{\mu\nu\rho}\left(\mathrm{tr}F^{\nu\rho} + \mathrm{tr}\tilde{F}^{\nu\rho}\right)$$

- For CFT: fluxes on S^2 of radially quantized CFT

Monopole operators in CSm & AdS/CFT

- Gauss' law: extra excitation of matter fields required

$$\frac{k}{4\pi} \star_3 F_\mu \sim J_\mu = i\left(\phi D_\mu \phi^\dagger - D_\mu \phi \phi^\dagger\right) + \cdots$$

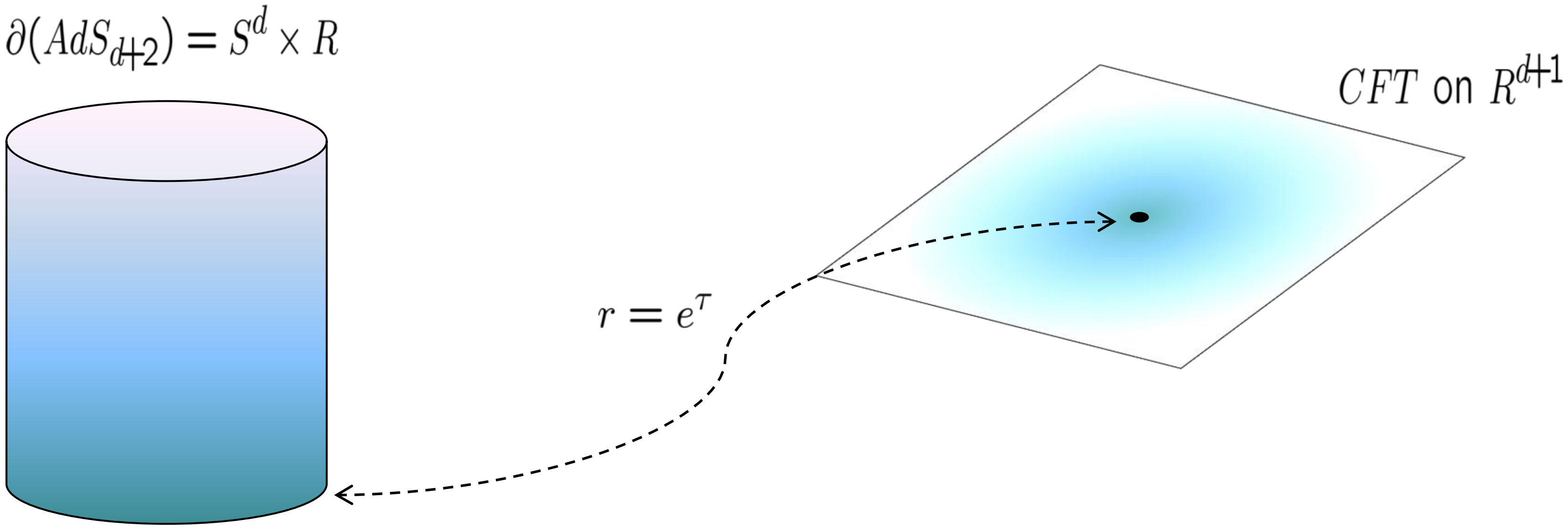
- Extra gauge invariant operators: gauge non-invariance screened by monopoles [dimension] ~ k
- Can provide extra currents for enhanced symmetry (at low enough k)
- Also, such extra local operators create KK states from IIA to M-theory: careful study needed to know various aspects of M-theory dual.

$$j_\mu \sim \frac{1}{2}\epsilon_{\mu\nu\rho}\left(\mathrm{tr}F^{\nu\rho} + \mathrm{tr}\tilde{F}^{\nu\rho}\right)$$

- Generally nonperturbative, & more difficulty in studying them at low k

“Spectrum” of local operators in 3d SCFT

- Simplest property of 3d CFT: the spectrum of local operators. (2pt functions)
- CFT can be put on S^d x R: map to spectrum of states
- With AdS dual, this theory dual to quantum gravity on global AdS_{d+2}:



- In simple AdS_5/CFT_4, examples (e.g. N=4 SYM), SUSY states probed by Witten indices are simple: free CFT [Kinney-Maldacena-Minwalla-Raju]
- Monopoles are non-perturbative: even BPS local operators are nontrivial.

Challenges for strongly interacting ABJM

- M2-branes: $N^{3/2}$ degrees of freedom at strong coupling.
- Expectation from gravity dual [Klebanov-Tseytlin (1996)]

$$S_{M2} = 2^{7/2} 3^{-3} \pi^2 N^{3/2} V T^2$$

- Reliable at large N limit: $\text{and } k \sim \mathcal{O}(1) \text{ or } \lambda \equiv \frac{N}{k} \gg 1$
- Weakly-coupled ABJM: ~N^2 degrees, as seen by classical QFT
- Strongly-coupled ABJM: reduction via strong-coupling effect?

Other strong coupling properties in 3d

- AdS_4/CFT_3 : many models with various SUSY (mostly from M2 physics)

- Mirror symmetry: combination of type IIB S-duality (+ IR limit)

- Seiberg duality: duality across strong-coupling point

- More dualities? Dualities proposed from M5-branes on 3-manifold: Some of them may shed more lights on string/M-theory itself…

Preview of next lectures

- Spectrum of local operators in 3d SCFT, including non-perturbative monopole operators

- Study via superconformal index:

$$I(\beta) = \mathrm{Tr}\left[(-1)^F e^{-\beta(H+\cdots)}\right]$$

trace over the space of local
(gauge invariant) operators

- Applications: (1) basic test of AdS/CFT, including ABJM, (2) During this course, one obtains a compelling evidence for SUSY enhancement of ABJM to N=8, (3) test other non-perturbative dualities in various 3d models, (4) learn various roles of CSm monopoles…

Preview of next lectures

- Observation of $N^{3/2}$ from 3-sphere partition functions [Drukker-Marino-Putrov (2010)] [Herzog-Klebanov-Pufu-Tesileanu (2010)] [Jafferis-Klebanov-Pufu-Safdi (2011)] [Martelli-Sparks (2011)] [Cheon-H.Kim-N.Kim (2011)]
- N=2 SCFT obtained by a RG fixed point of certain UV theories
- Determination of U(1) R-symmetrtry: mixing of various U(1) flavors

$$R = R_0 + \sum_j a_j F_j$$

- The 3-sphere partition function can also be used to determine superconformal U(1) R-symmetry from UV data (under certain assumptions) [Jafferis (2010)]