On M5 Branes

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Hee-Cheol Kim, Seok Kim, Sung-Soo Kim, KM [arXiv:1307.7660] The general M5-brane superconformal Index

Hee-Cheol Kim, KM [arXiv:1210.0853] M5 brane theories on R x CP2

Hee-Cheol Kim, Seok Kim, Eunkyung Ko, KM [arXiv:1110.2175] On instantons as KK modes of M5 branes

Stefano Bolognesi, KM [arXiv:1105.5073] 1/4 BPS string junctions and N3 problem in 6-dim conformal field theories

6d (2,0) Superconformal Theories

- A, D, E type: type IIB on R^{1+5} x C^2/Γ_{ADE}
  - A_{N-1}, D_N type on N M5 branes, N M5 (+OM5)
- superconformal symmetry: $OSp(2,6|2) \supset O(2,8)$ x $USp(4)_R$
- fields: B, $\Phi_{I\ (I=1,2,3,4,5)}$, Ψ : 3 + 5+ 8 d.o.f.
  - selfdual strength H=dB=*H, purely quantum $\hbar=1$
  - Weyl and symplectic-Majorana Ψ
- Nonabelian formulation?.
  - Sorokin, Chu, Ho, Lambert, Papageorgakis, Samtleben et.al, ...
  - Their 4d-reduction implies a local nonabelian field theory which has both electric and magnetic objects.
- N^3 degrees of freedom

Outline

- Goal: Calculate Something Concrete!
- 5d Approach: R^{1+4}
  - instantons
  - 1/4 BPS webs
  - index function of dyonic instantons
  - DLCQ
- 6d approach: RxS^5
  - Twisting
  - Z_K-moding
- 5d approach: $RxCP^2$
  - Minkowski and Euclidean Lagrangian
  - Index function
- Conclusion

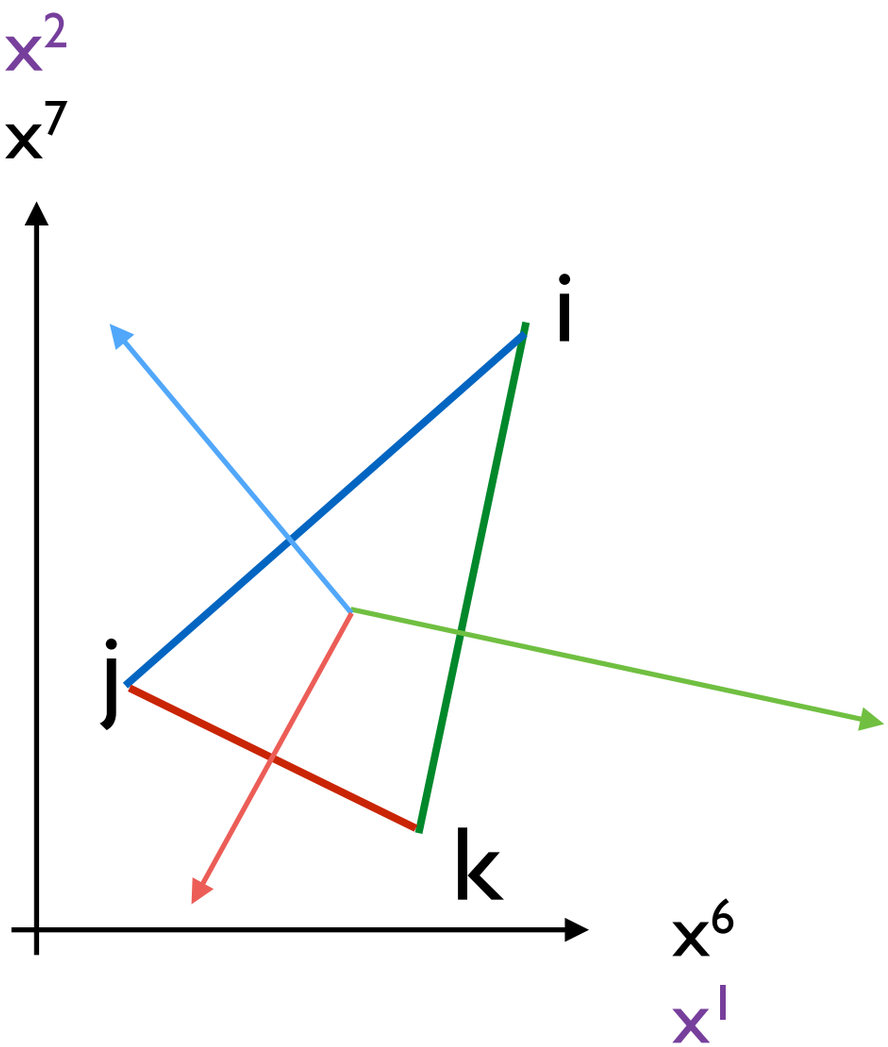
5-dim Approach

- Douglas, Lambert-Papageorgakis-Schmidt-Sommerfeld
- $x5 \sim x5 + 2\pi R$, 5d N=2 U(N) YM Theory
- Instantons= Kaluza-Klein modes , $4\pi / g^2 = 1/R$
  - threshold bound states of k instantons for Kaluza-Klein momentum k
  - strong coupling limit is 6d (2,0) theory
- perturbative approach: problem at 6-loop (Bern et.al. 1210): mysterious
  - incomplete? (Need higher order operators to complete the theory?)

1/4 BPS String Junctions

- Monopole strings, self-dual strings in Higgs phase
- count 1/2 BPS & 1/4 BPS objects: structure constants: f^{ijk} $f^{\alpha-\alpha h}$, $f^{\alpha\beta\gamma}$

$$\frac{N(N-1)}{2} + \frac{N(N-1)(N-2)}{6} = \frac{N(N^2-1)}{6} = h_G d_G$$



Dyonic Instantons in 5d N=2 SYM

- Index for BPS states with k instantons

$$Q = Q^{\dagger}_{+} \qquad \left.\begin{matrix} SU(2)_{2R} \\ SU(2)_{1R} \end{matrix}\right\} \Rightarrow SU(2)_R$$

$$I_k(\mu^i, \gamma_1, \gamma_2, \gamma_3) = \mathrm{Tr}_k \left[(-1)^F e^{-\beta Q^2} e^{-\mu^i \Pi_i} e^{-i\gamma_1(2J_{1L}) - i\gamma_2(2J_{2L}) - i\gamma_R(2J_R)} \right]$$

adjoint hyper flavor

  - μ_i : chemical potential for $U(1)^N \subset U(N)_{color}$
  - $\gamma_1, \gamma_2, \gamma_R$: chemical potential for $SU(2)_{1L}, SU(2)_{2L}, SU(2)_R$

- calculate the index by the localization:

$$I(q, \mu^i, \gamma_{1,2,3}) = \sum_{k=0}^{\infty} q^k I_k$$

- 5d *N=2** instanton partition function on $R^4 \times S^1$: $t \sim t + \beta$

- In $\beta \to 0$ and small chemical potential limit, the index becomes 4d Nekrasov instanton partition function :

$$a_i = \frac{\mu_i}{2} \qquad -\epsilon_1 = i\frac{\gamma_1 - \gamma_R}{2} \qquad \epsilon_2 = i\frac{\gamma_1 + \gamma_R}{2}, \quad m = i\frac{\gamma_2}{2} \qquad q = e^{2\pi i \tau}$$

Scalar Vev

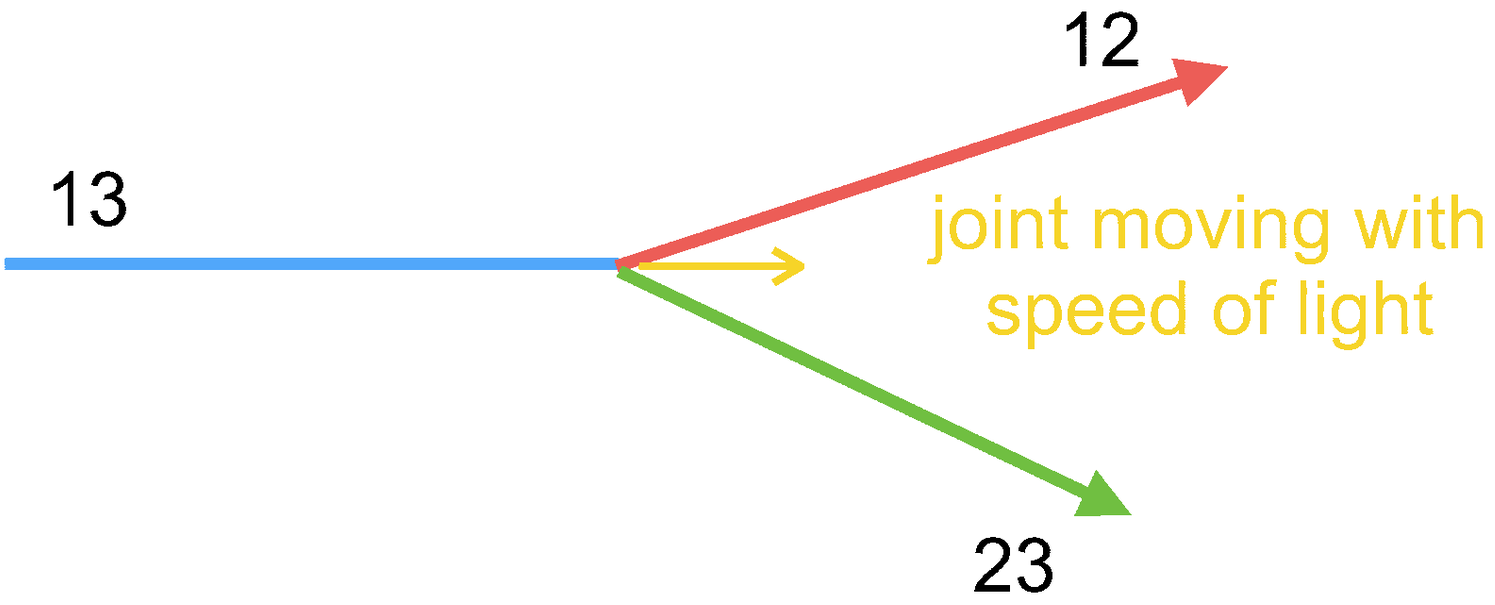
Omega deformation parameter

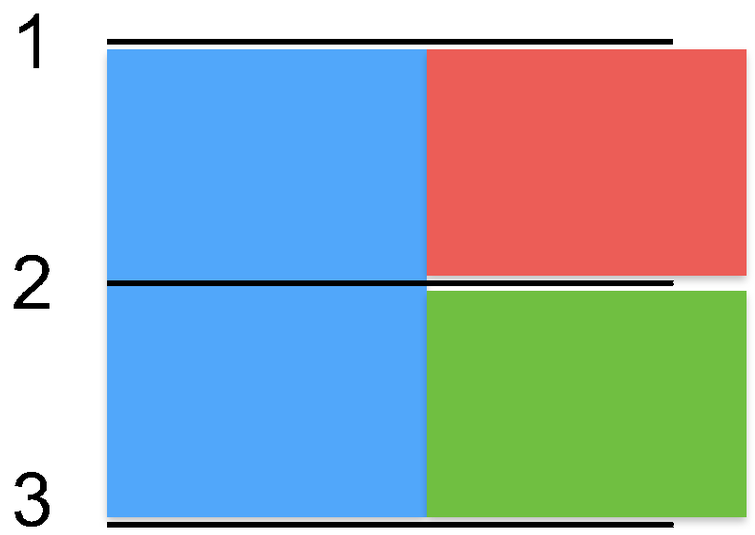
Adj hypermultiplet mass

instanton fugacity

Most striking aspect

- Additional States appearing in dyonic instanton calculations
- Can be regarded as the degenerate limit of junctions
- There is a threshold bound states of W-boson for 13 and instantons on 2nd M5 branes





High Temperature in Coulomb Phase

- Micro-canonical
- Massless on N M5 branes: O(N)
- Loops of self-dual strings excitations: $O(N^2)$
- Beyond the Hagedorn temperature
- Webs of junctions and anti-junctions: $O(N^3)$
- Higher order of junctions can be decomposed to elementary junctions
- Excitations of webs of tensionless strings with junctions act as atoms.
  - N^3 degrees of freedom