# *Black Hole Attractors and Superconformal Quantum Mechanics*

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# *Contents*

- *Brief review:*
  - *BPS black holes in* $\mathcal{N} = 2$ *supergravity*
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  - *Short multiplets*

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- *BH entropy from* $D2$*-brane wrapping horizon.*

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- $F_A = \partial_A F = \partial_A \left[ \frac{D_{abc} X^a X^b X^c}{X^0} + \cdots \right]$

# BPS Black Holes

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- Dependence is forgotten near the horizon
- $X^A(r) \to X^A_{fixed}(p^A, q_A)$ as $r \to 0$
  - Scalars flow to an attractor point

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- $X^A_{fixed}$ *extremizes* $|Z| = |p^A F_A - q_A X^A|$
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- $\mathfrak{Re}\; C X^A_{fixed} = p^A \qquad \mathfrak{Re}\; C F_{A\,fixed} = q_A$
- $S_{BH}(p,q) = \pi |Z|^2_{fixed}$
- $\exp S_{BH}(p,q) \simeq$ *Number of microstates of black hole*

# Entropy from microstates

- *Charges* $\binom{p^A}{q_A}$ *from D-branes in Calabi-Yau*

$$(p^0, p^a, q_a, q_0) \qquad (D6, D4, D2, D0)$$

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- *Counting of bound states of* $D4, D2, D0$
  - $S_{BH}(p,q) \simeq 2\pi\sqrt{D\tilde{q}_0}$
  - $D = D_{abc}p^a p^b p^c \qquad \tilde{q}_0 = q_0 + \frac{1}{12}D^{ab}q_a q_b$

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  - *Different computations: M-theory, others.*
  - $\prod \frac{1}{(1-x^n)^{6D}}$

# Probing near the horizon

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- $AdS_2/CFT_1$ *correspondence:*
  - *Superconformal Matrix Quantum Mechanics?*

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- $$q_e R \int \frac{\mathrm{d}t}{\sigma} + q_m R \int \mathrm{d}\phi \cos\theta$$
- *Charges* $\binom{u^A}{v_A}$ $\quad m = \left|u^A F_A - v_A X^A\right|$
- $q_m = p^A v_A - q_A u^A \qquad q_e^2 + q_m^2 = m^2$

# Hamiltonian

- *Hamiltonian to quadratic order* ($\sigma = \xi^2$)
- $\frac{1}{8mR}\hat{P}_\xi^2 + \frac{1}{2mR\hat{\xi}^2}\hat{L}_{S_2}^2 + \frac{1}{2mR\hat{\xi}^2}\hat{\Delta}_{CY}$

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- $SU(2)$ *R-symmetry* $\hat{L}_i^{tot} = \hat{L}_i^{S_2} + \hat{L}_i^{spin}$
- $\hat{L}_{\alpha\beta}^{tot} = \hat{L}_i^{tot}\sigma_{\alpha\beta}^i$

# Fermions

- Fermionic partners: $D0$ brane has $16$ in $10d$ spinor $\Theta$
- $\Theta = \lambda_\alpha u + \eta_\alpha^a \Gamma_a u + \bar{\eta}_\alpha^{\bar{a}} \Gamma_{\bar{a}} \bar{u} + \bar{\lambda}_\alpha \bar{u}$

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- $\{q^A_\alpha, q^B_\beta\} = \hat{\Delta}_{CY} \epsilon_{\alpha\beta} \epsilon^{AB}$
- *R-symmetry* $SU(2)$ *acts as Lefshetz action on* $(p,q)$*-forms* $(J\wedge, (p-q)/2, \imath(J))$

# Fermionic symmetries

- $\{\hat{S}^A_\alpha, \hat{S}^B_\beta\} = 2\epsilon^{AB}\epsilon_{\alpha\beta}\hat{K}$
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- $\{\hat{S}^A_\alpha, \hat{Q}^B_\beta\} = \epsilon^{AB}(\epsilon_{\alpha\beta}\hat{D} + 2i\hat{L}^{tot}_{\alpha\beta})$

# Supersymmetry generators

- $\hat{Q}^A_\alpha = \frac{1}{\hat{\xi}}\hat{q}^A_{\alpha,CY} +$
  $(\frac{1}{2}\hat{P}_\xi \lambda^A_\alpha - \frac{i}{\hat{\xi}}(\hat{L}^{S_2}_{\alpha\beta} + \hat{L}^{CY}_{\alpha\beta} + \frac{1}{2}L^\lambda_{\alpha\beta})\lambda^{A\beta}$

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- $\{\hat{Q}^A_\alpha, \hat{Q}^B_\beta\} = 2\epsilon^{AB}\epsilon_{\alpha\beta}\hat{H}$
- *Nontrivial cancellations at work.*
- $\hat{H} = \frac{1}{8mR}\hat{P}^2_\xi + \frac{1}{2mR\hat{\xi}^2}\hat{L}^2_{tot} + \frac{m}{R\hat{\xi}^2}\hat{\Delta}_{CY} + \cdots$

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- *In short multiplet also* $G^A_{+,-\frac{1}{2}}$

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- Difficult to write Matrix SCQM

# $D2$-branes wrapping $S^2$

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- *Magnetic field on CY :* $F_{a\bar{b}} = \sum p^A \alpha_A = J_{a\bar{b}}$
- *Magnetic field changes anticommutator of* $q^A_\alpha$
- $\{q^A_\alpha, q^B_\beta\} = \hat{H}^{CY} \epsilon_{\alpha\beta} \epsilon^{AB} + c' L^{CY}_{\alpha\beta} \sigma_1^{AB}$
- *Spurious term in* $\{Q^A_\alpha, Q^B_\beta\}$

# Corrected supercharge

- $\hat{Q}^A_\alpha = (\frac{1}{2}\hat{P}_\xi \lambda^A_\alpha - \frac{i}{\hat{\xi}}(\hat{L}^{CY}_{\alpha\beta} + \frac{1}{2}L^\lambda_{\alpha\beta}))\lambda^{A\beta} +$
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- $\{\hat{S}^A_\alpha, \hat{Q}^B_\beta\} = \cdots + c(\sigma_1)^{AB}\epsilon_{\alpha\beta}$
- *Central extension from charge of* $D2$ *on sphere*

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- Highest weight killed by one $G_{-\frac{1}{2}}$ only
- Ground states from Landau levels on Calabi Yau.
- Leading order $4D$ bosonic ground states, $4D$ fermionic
- $D = D_{abc}p^a p^b p^c$

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- Asymptotic number of states $\exp(2\pi\sqrt{Dq_0})$

# Conclusions

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- Why is it interesting?
  - $Z_{BH} = \sum_q \Omega(p,q) e^{-q_A \phi^A} \simeq |Z|^2_{top}$
  - $\Omega(p,q)$ is number of bound states: open string theory, ignore attractor eqn.
  - $|Z|^2_{top}$ is closed string topological partition function at the attractor point!
- Natural to seek explanation in attractor geometry.

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- Full Matrix SCQM for $AdS_2/CFT_1$