The Power of Supergravity Solutions

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GGI, 8 September 2016

Overview

1. Intro

2. Singularity resolution: Black hole microstates

   1512.05376 with Bena, Mayerson, Puhm

3. SUSY breaking: Anti-branes

   1507.01022 with **Diego Cohen-Maldonado**, Diaz, Van Riet

   1610.xxxxx with Aalsma, van der Schaar

   (work with Kallosh, Wrase '16 → see Timm talk)

4. Outro

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4. Outro

"Supergravity Knows"

- About quantum gravity/string theory

- Theories:
  - UV properties Zvi Bern talk
  - Hidden symmetries, DFT & EFT
  - Embedding tensor, (non-geometric) fluxes

- Solutions: this talk

"Supergravity Knows"

- Solutions know about quantum gravity/strings
  - Singularity resolution

    Lin-Lunin-Maldacena; Polchinski-Strassler; Klebanov-Strassler; Enhancon, KK monopoles ...
  - Holography: boundary unitarity, causality...

    [bulk reconstruction community]
  - SUGRA and DBI

    Denef '00; Bena, Bobev, Ruef, Warner '08; Bena, Puhm Vasilakis, Warner '13

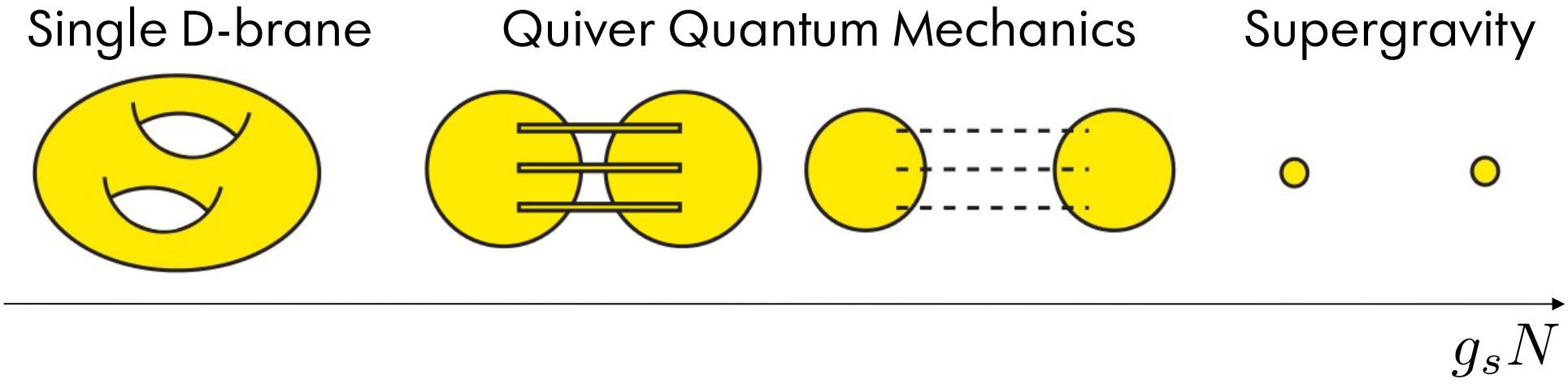
- SUGRA versions of String Theory mechanisms

SUGRA mechanisms

- Multi-center black holes

Cardoso, de Wit, Kappeli, Mohaupt '00;

Denef '00, '02

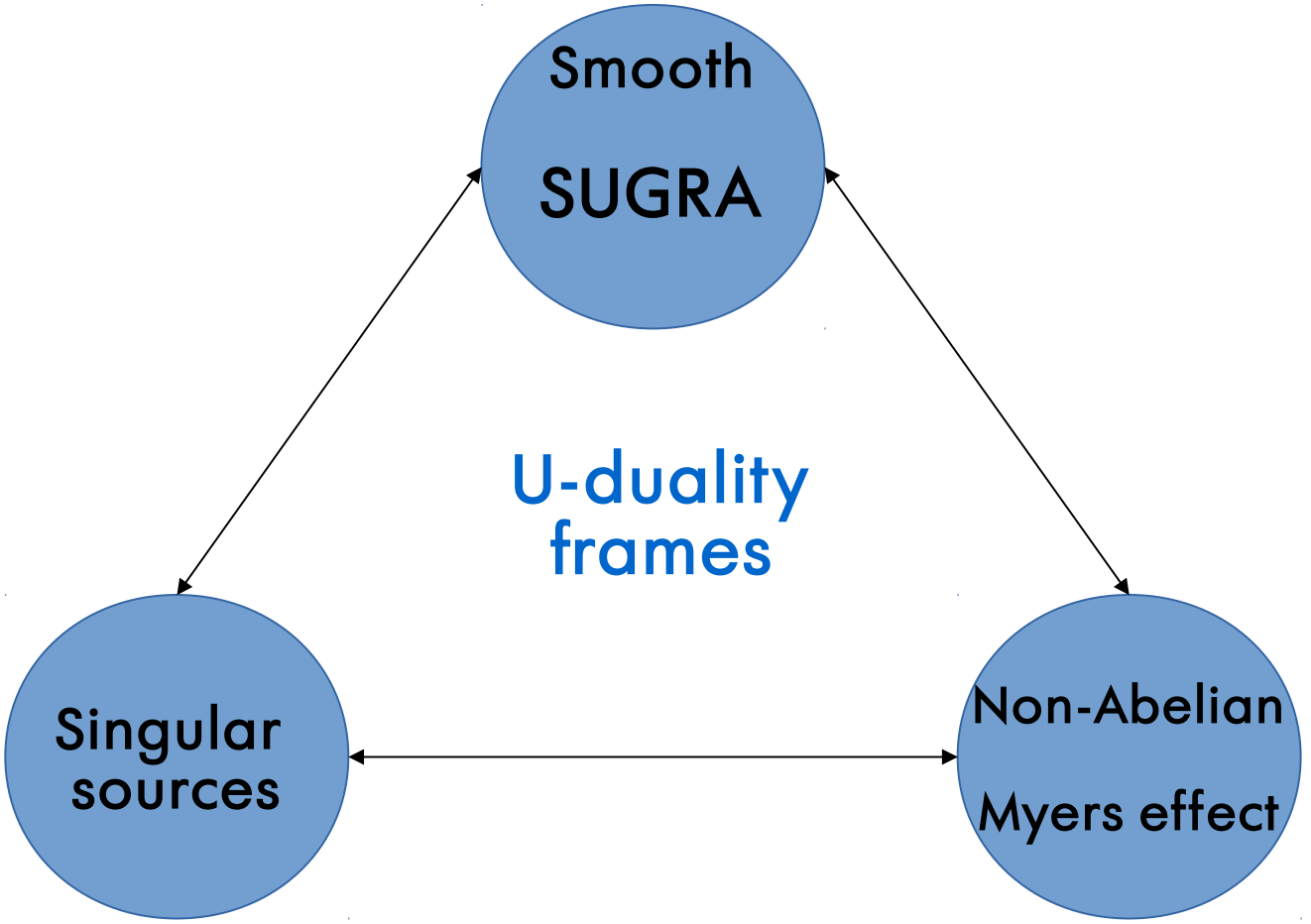


- Phase space & microstate counting

BPS indices and wall-crossing

SUGRA mechanisms

- SUSY Microstate geometries: horizon-less



"Supergravity Knows"

- SUGRA versions of String Theory mechanisms

- Guide to new physics!

    1) Singularity resolution

    2) SUSY breaking

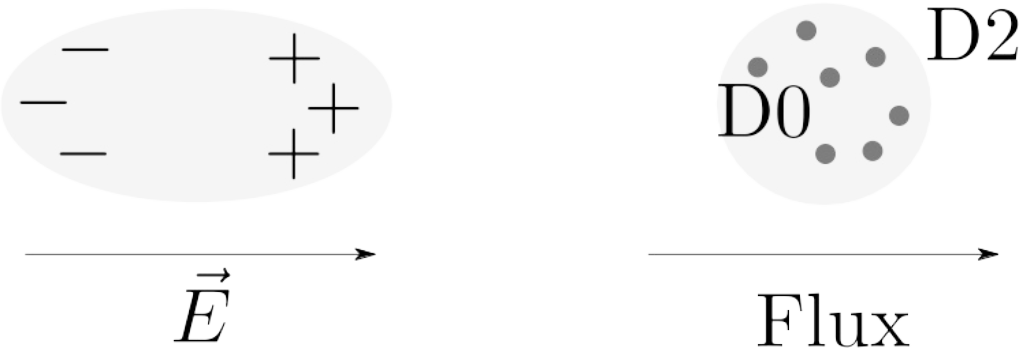
Chern-Simons Couplings

- Action: topological terms

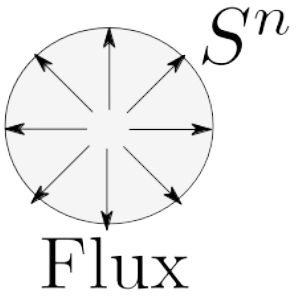
Type IIB: $dF_5 = H_3 \wedge F_3$

1) Charge dissolved in flux – Singularity resolution

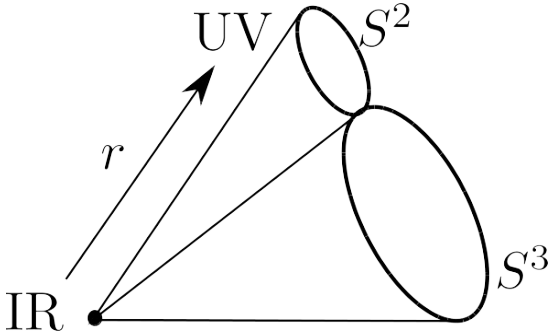
2) Dipole effect – SUSY breaking

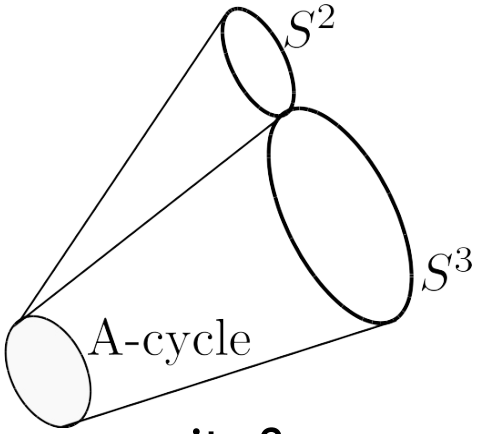


1) Singularity resolution

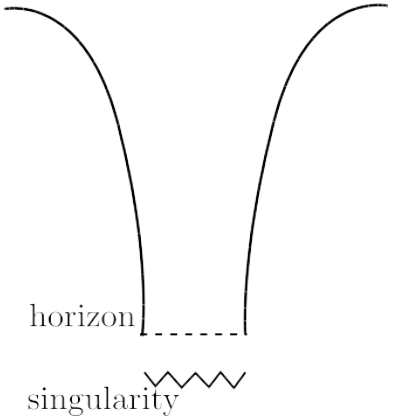


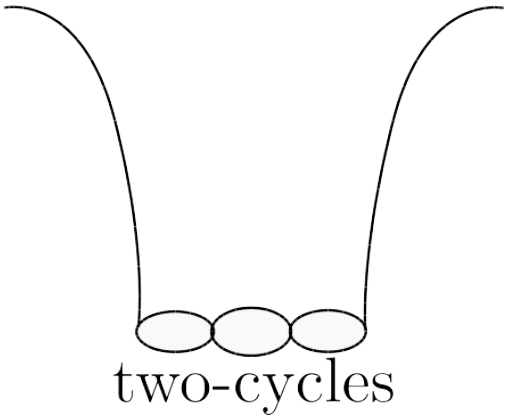
- Charge dissolved in flux: topology and new IR phases
  - Deformed conifold: Klebanov-Strassler '00





  - Microstate geometries → quantum gravity?





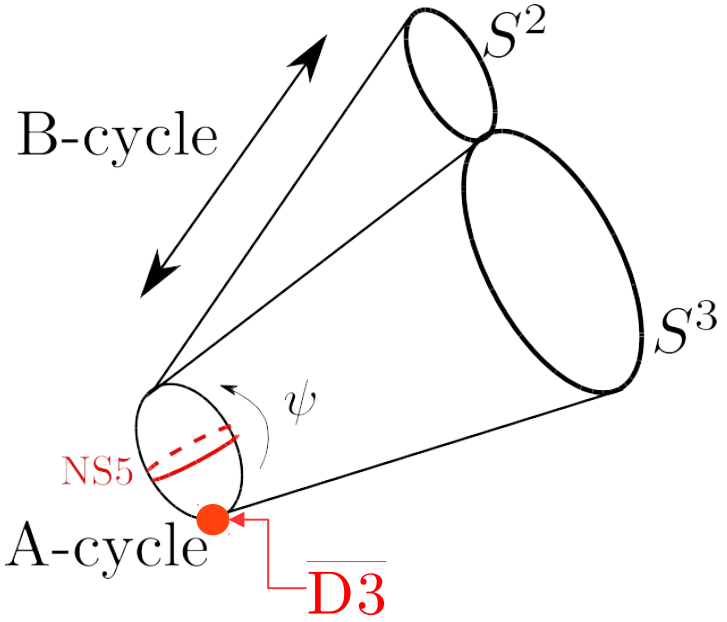
Denef; Lunin, Mathur; Skenderis-Taylor; Bena-Warner, de Boer, Giusto-Russo, Peet, Ross ...

2) SUSY breaking

Klebanov-Strassler

IIB $M_4 \times X_6$

polarize: $\overline{\text{D3}} \rightarrow$ NS5

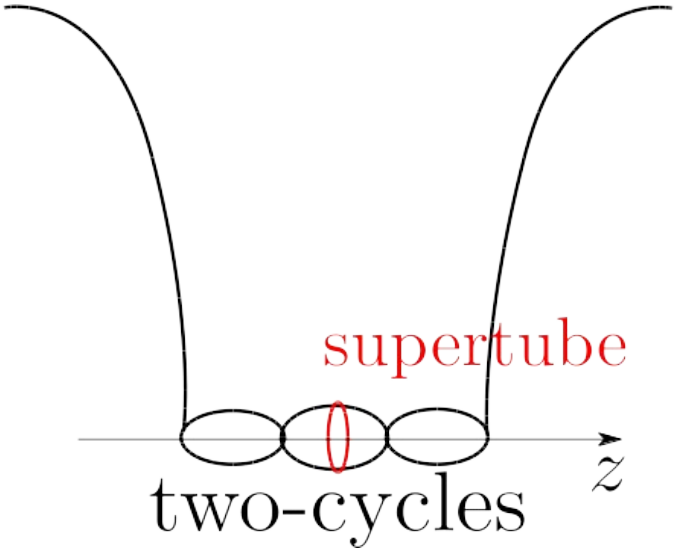


Kachru, Pearson, Verlinde '01

Microstate geometry

M-theory $M_5 \times T^6$

polarize: M2-M2 → M5



Bena, Puhm, BV '11, '12

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Black Hole Problems

- Black hole entropy

$$S = \frac{A_H}{4G_N}$$

- Singularity
- Information paradox

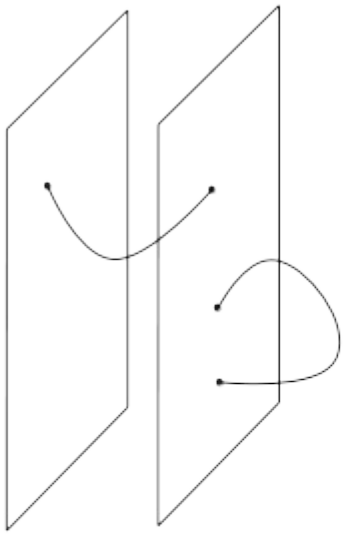
- Structure at horizon – Mechanism?
  - Firewalls? → no mechanism!
  - Black hole microstates

Black Hole Microstates

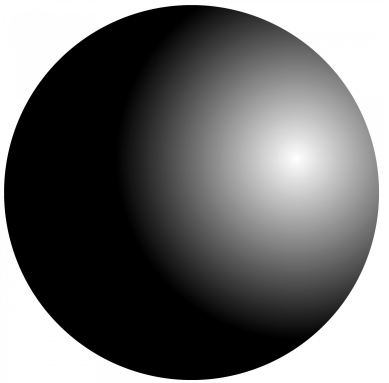
Strominger-Vafa '96

$\mathrm{M}_5 \times S^1 \times T^4$

"D1-D5-P black hole"



$G_N \sim g_s^2$ larger

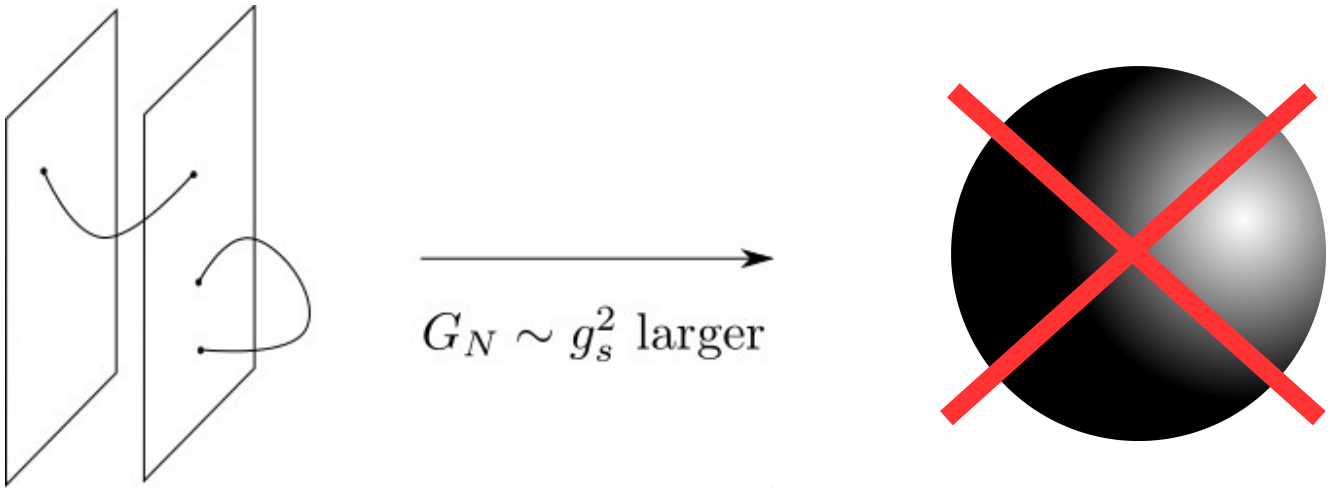


$S_{\text{micro}} = \log(N_{\text{micro}})$ ⟷ $S_{\text{macro}} = \frac{A_H}{4G_N}$

protected (susy)

Black Hole Microstates

- Gravitational interpretation?



  - "No stationary solitons without horizons … or topology"

$$M_{ADM} = \int_{horizon}(\ldots) + \int_{space} H_2 \wedge F_2$$

Gibbons-Warner '13

  - Microstate geometries

SUSY microstate geometries

- **Before 2011**
  - D1-D5: very successful

    Lunin-Mathur; Lin, Maoz, Maldacena; Skenderis, Kanitscheider, Taylor ...
  - D1-D5-P Only large families known 5d

    Bena, Wang, Warner; Potvin, Peet; Balasubramania, Gimon, Levi

- **After 2011**
  - 6 dimensional "superstrata" Bena, de Boer, Shigemori, Warner '11

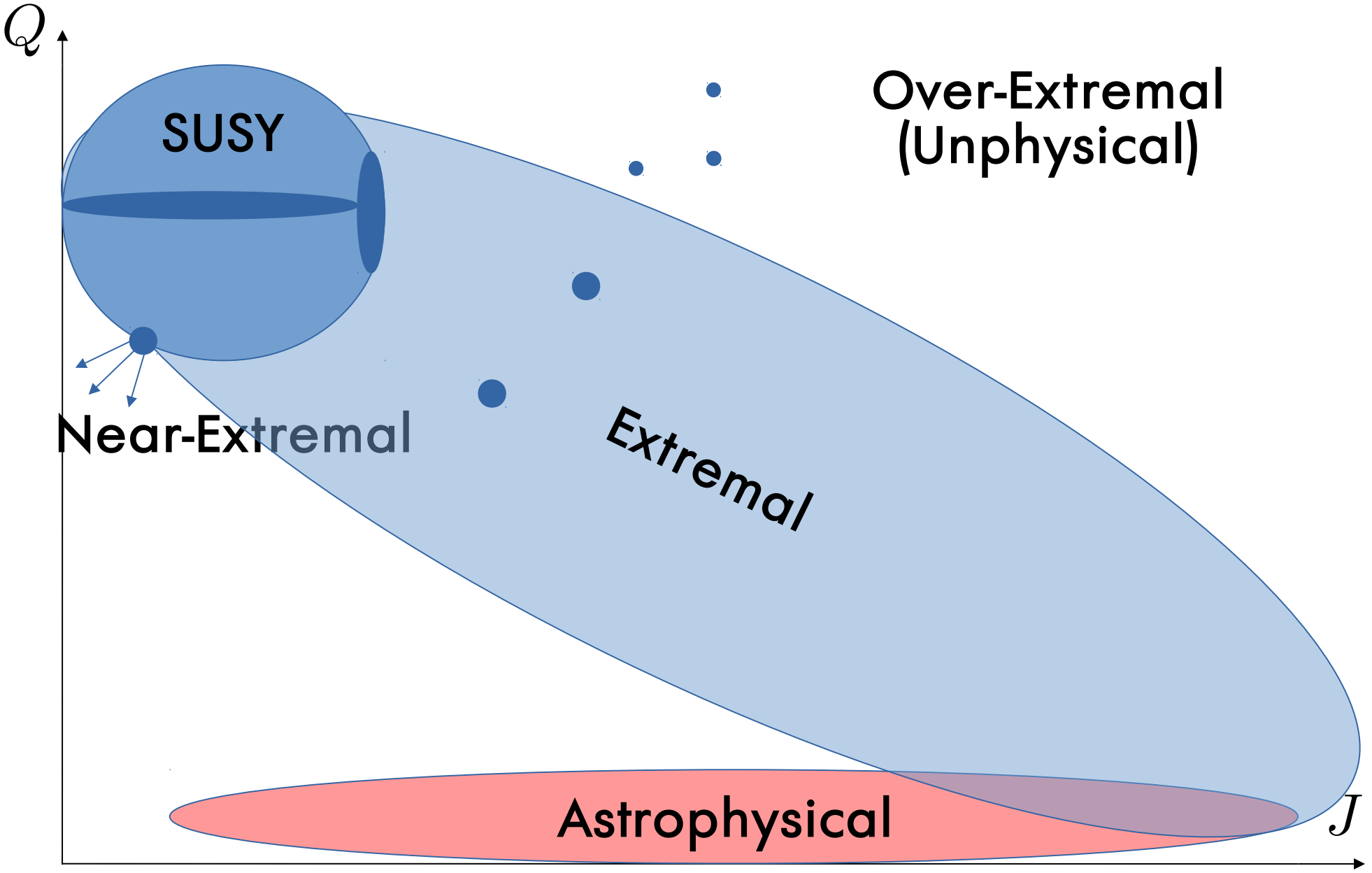
    Bena, Giusto, Martinec, Russo, Turton, Warner '15-'16

$$\overbrace{M_5 \times S^1}^{M_6} \times T^4 \xrightarrow{\text{asymptotically}} M_5 \times S^1 \times T^4$$

  - Most general with D1-D5-P supersymmetries and rigid T^4

    Giusto, Martucci, Petrini, Russo '13

Our Current Understanding

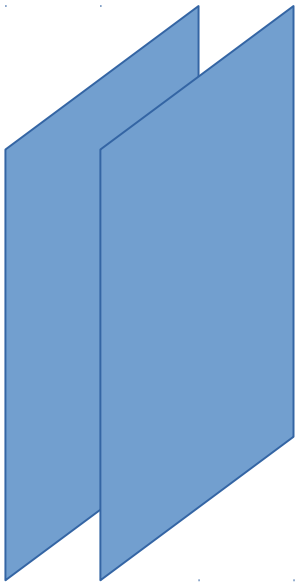


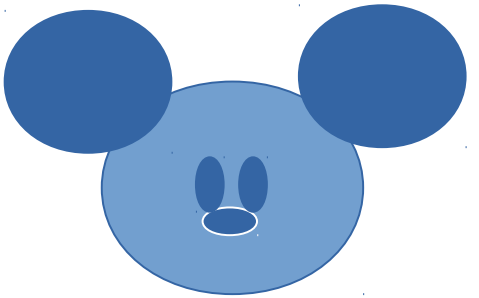
Beyond SUSY?

- New stationary solutions? (group theory …)
- Time-dependent solutions?
- Infall?

- This talk:
  - Formation of microstates in collapse
  - Near-SUSY

Classical or quantum?





Collapsing matter
(branes)

Microstate
geometry

Classical or quantum?

Cumulative tunneling rate $\Gamma_{tot} = \mathcal{N} \times \Gamma$

Mathur '08; Mathur-Kraus '15

- Dimensional analysis

$$\Gamma = \exp(-\alpha S_{BH})$$

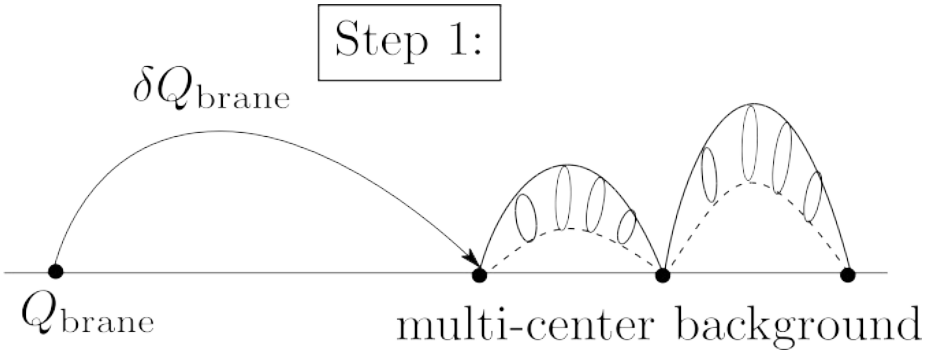
- Tunneling happens provided

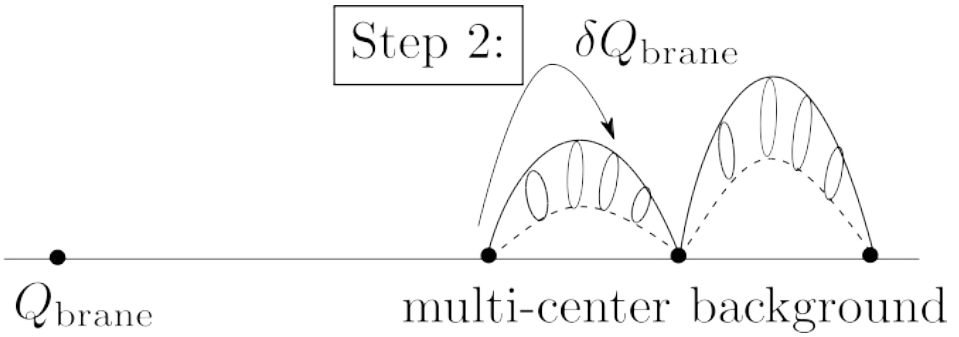
$$\mathcal{N} = \exp(S_{BH}) \qquad \text{and} \qquad \alpha \leq 1$$

Quantum Tunneling

- Calculation for near-extremal solutions

Bena, Puhm, BV '15





- Result for N-bubble end state

$$\Gamma_N = \exp(-\alpha S_{BH}), \qquad \alpha = N^{-\beta} < 1$$

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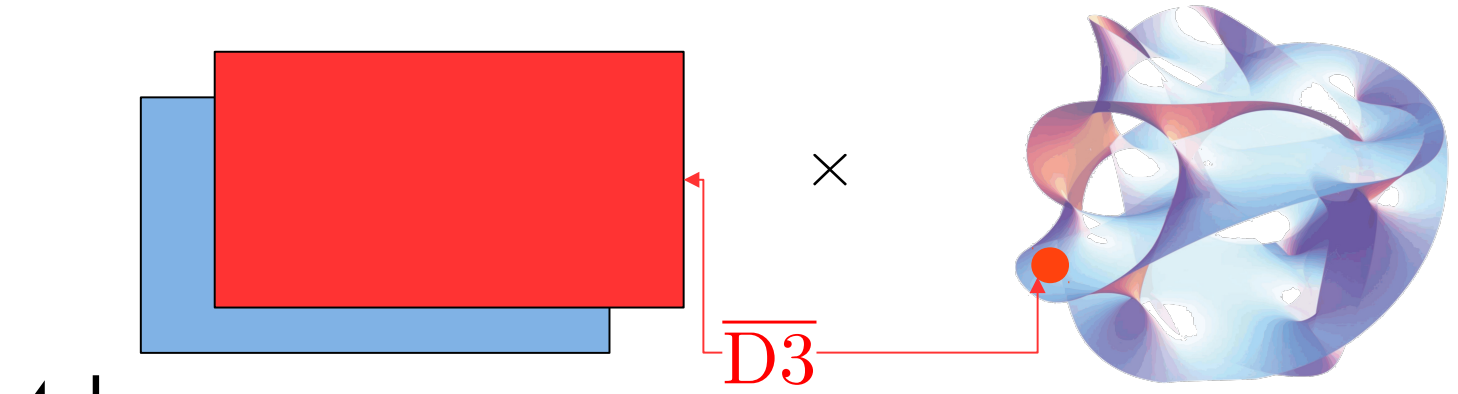
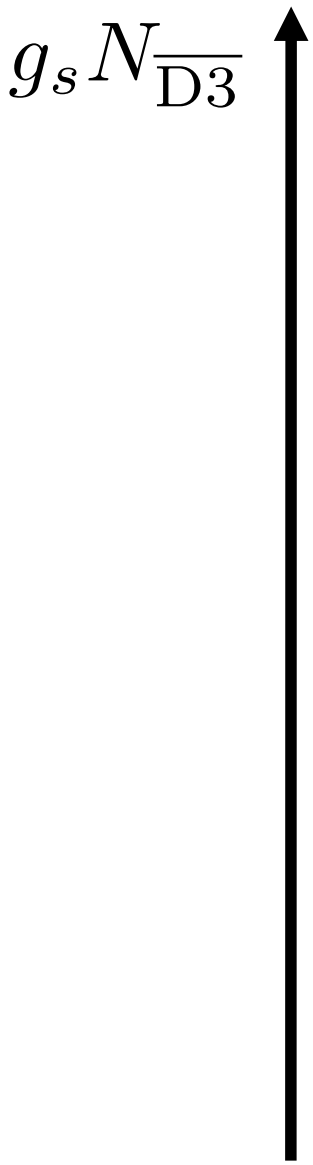
Anti-branes in fluxes

- Applications
  - SUSY breaking in string/field theory
  - de Sitter Kachru, Kallosh, Linde, Trivedi '03 + audience
  - Prototype for BH microstate geometries

- Riding horse



Different Regimes



10d supergravity

- Many no-go results

10d string theory

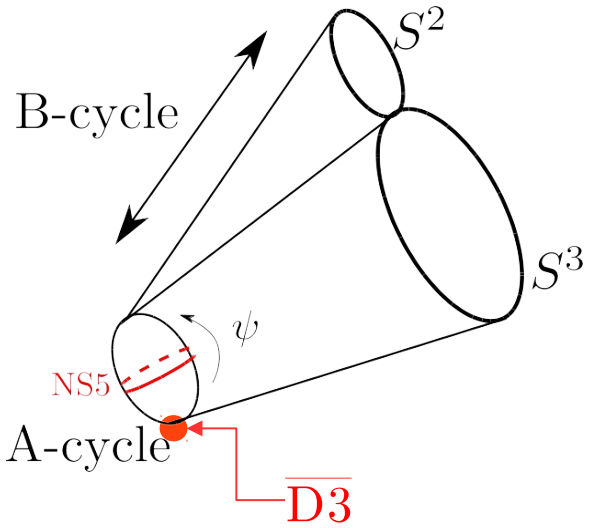
- 4d supergravity

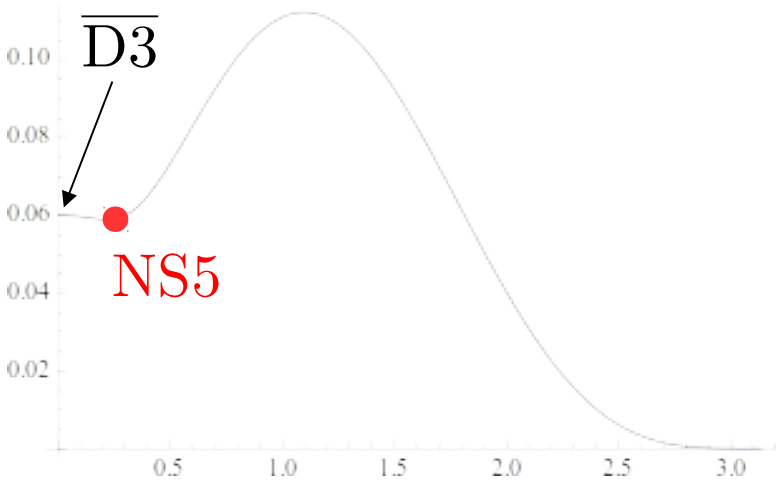
(constrained superfields)

10d SUGRA: $g_s N_{\overline{D3}} \gg 1$

- Probe anti-branes

Kachru, Pearson, Verlinde '01





- Back-reaction: many no-go statements

McGuirk, Shiu, Sumimoto '09; Bena, Grana, Halmagyi '09
Saclay group; Uppsala group; Hannover, Leuven … '09 – '16

… But polarization largely ignored!

10d SUGRA: Our work

- No-go theorems:

$$\mathrm{e}^{-\phi}|H_3|^2 \to \infty$$

- Based on mass considerations

Gautason, Junghans, Zagermann '13

Blaback, Danielsson, Junghans, Van Riet, Vargas '14

$$M = \int (\text{boundary term})$$

- Re-investigate for NS5 polarization:

no-go result no longer holds!

Cohen-Maldonado, Diaz, Van Riet, BV '15

10d string: $g_s N_{\overline{D3}} \ll 1$

Single anti-D3 (no polarization!)

- EFT consistent: small corrections

  Michel, Mintun, Polchinski, Puhm, Saad '14

- Language: Constrained superfields

  Ferrara, Kallosh, Linde '14

  anti-D3: Kallosh, Wrase '14; Bergshoeff, Dasgupta, Kallosh, Van Proeyen, Wrase '15, Kallosh, BV, Wrase '16

  general formalism: > half the audience

See talks Anna Karlsson, Timm Wrase

10d string: Corrections

- Corrections to constraints? [talk Anna Karlsson]

$$K = S\bar{S} + c\frac{(S\bar{S})^2}{\Lambda^2} \xrightarrow{c \to \infty} S^2 = 0$$

- Heavy field X in particular SUGRA model

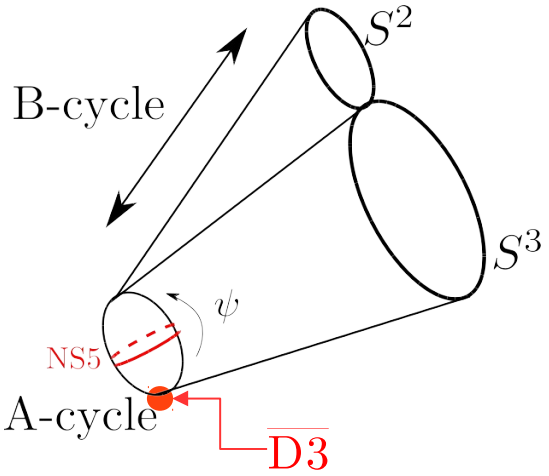
$$K_{1-\text{loop}} = \frac{\lambda}{m_X^2}\frac{(S\bar{S})^2}{\Lambda^2}$$ Dudas, Heurtier, Wieck, Winkler '16

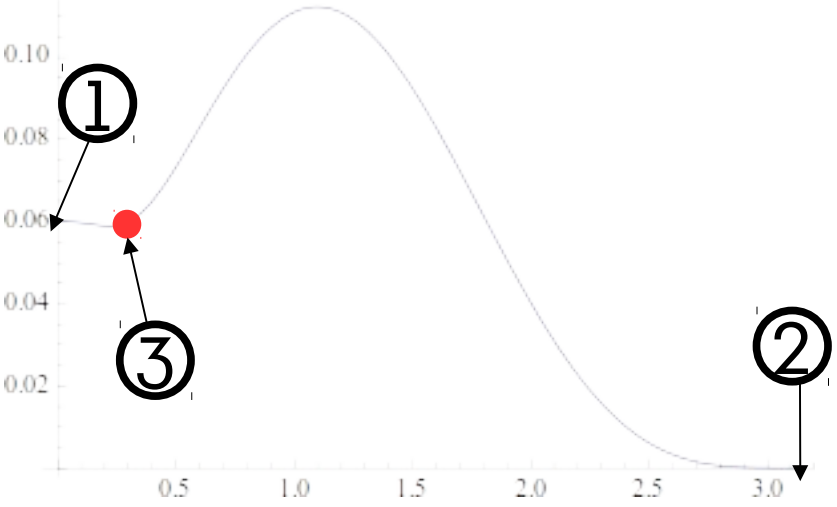
- Corrections in string theory?

10d string: Our work

- NS5 polarization: 4d interpretation

Aalsma, van der Schaar, BV 1610.xxxx





- Goldstino and massive field ψ

① $\overline{\text{D3}}$ ⟶ Nilpotent Bergshoeff, Dasgupta, Kallosh, Van Proeyen, Wrase '15

② D3 ⟶ SUSY, fields λ, ψ

③ NS5 ⟶ Nilpotent + corrections set by $N_{\overline{D3}}$

Overview

1. Intro: Examples

2. Black holes and microstates

3. SUSY breaking and anti-branes

4. Outro

Outlook

- SUGRA knows and shows

- Singularity resolution and Black hole Microstates
  - Time-dependent solutions? Observations?
  - Classical collapse?

- SUSY breaking and constrained superfields
  - Full understanding in string theory?