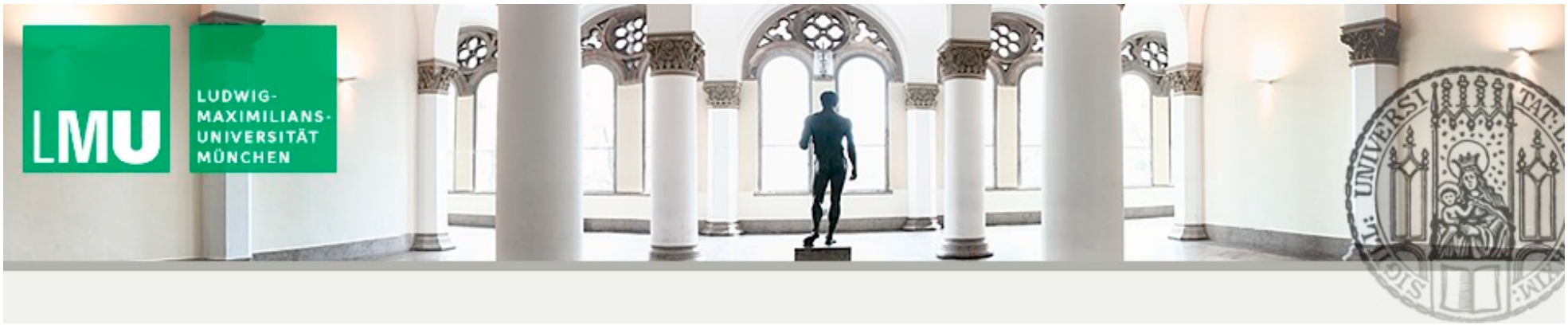
The Landscape of String theory

Dieter Lüst, LMU (ASC) and MPI München



HEP 2007, Manchester

LMU

MAX-PLANCK-GESELLSCHAFT

The Landscape of String theory

Dieter Lüst, LMU (ASC) and MPI München

in collaboration with

Riccardo Appreda, Ralph Blumenhagen, Gabriel L. Cardoso, Mirjam Cvetic, Johanna Erdmenger, Florian Gmeiner, Viviane Grass, Michael Haack, Daniel Krefl, Gabriele Honecker, Jan Perz, Susanne Reffert, Robert Richter, Christoph Sieg, Maren Stein, Stephan Stieberger Antoine van Proeyen, Timo Weigand and Marco Zagermann

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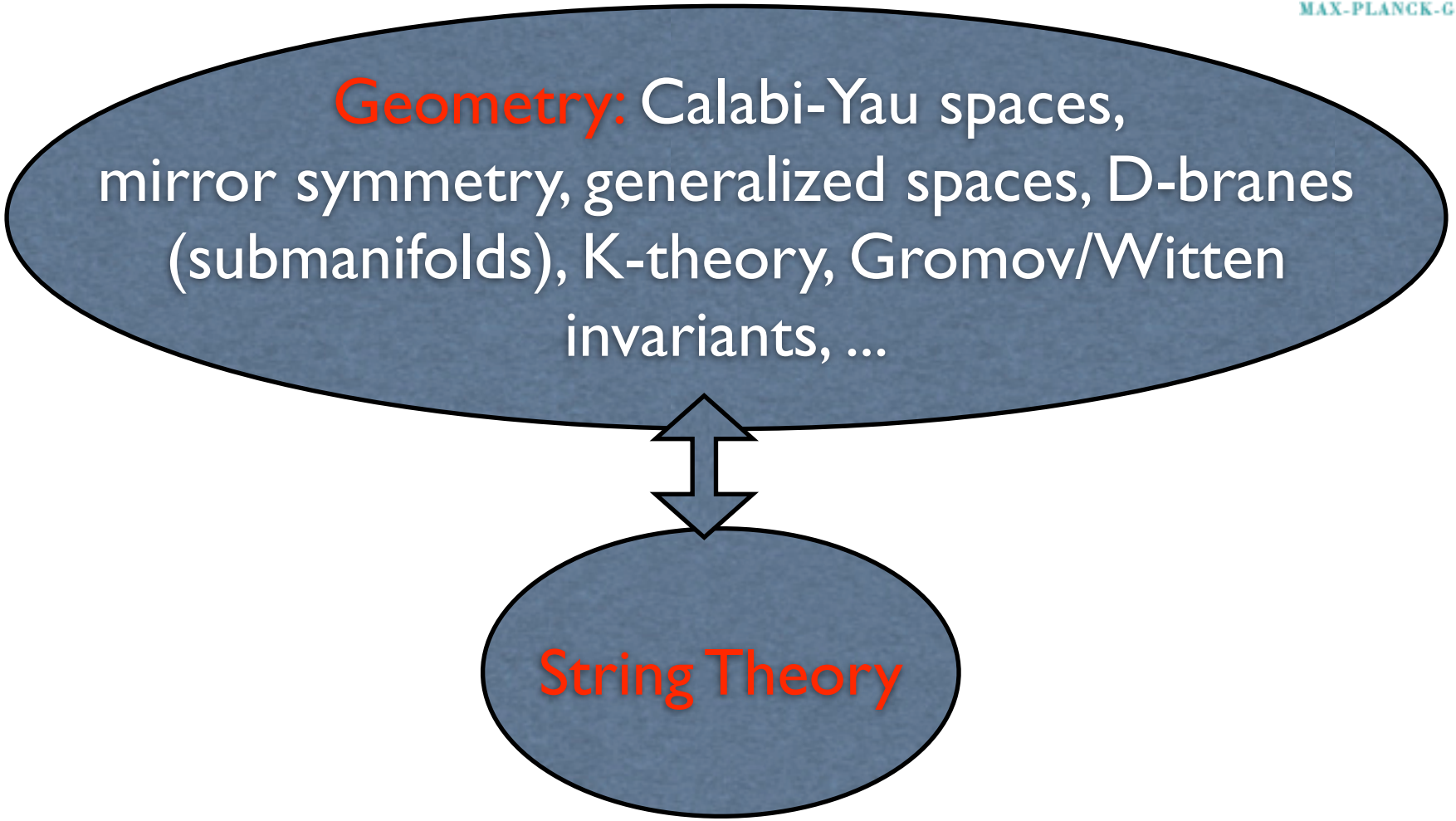

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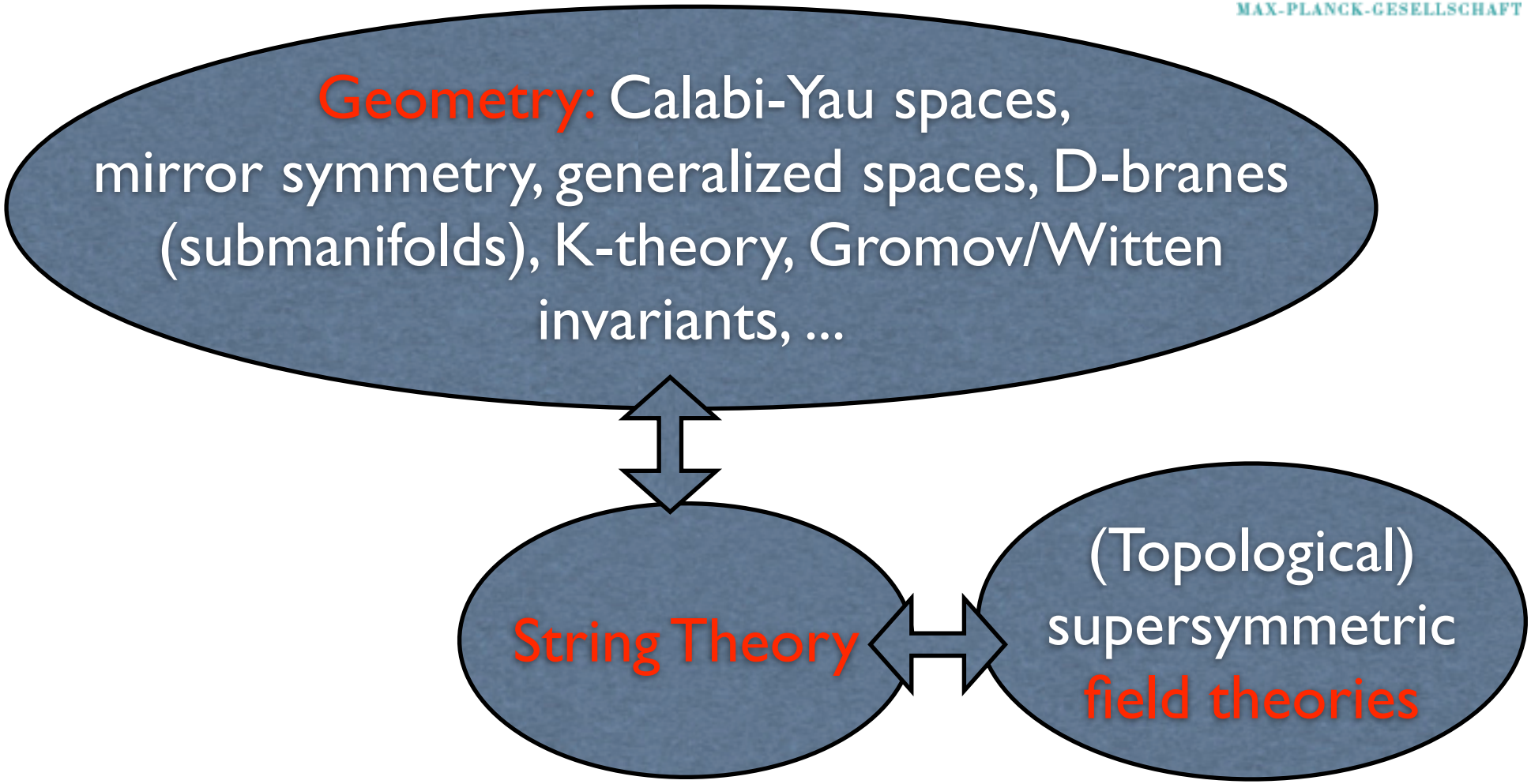

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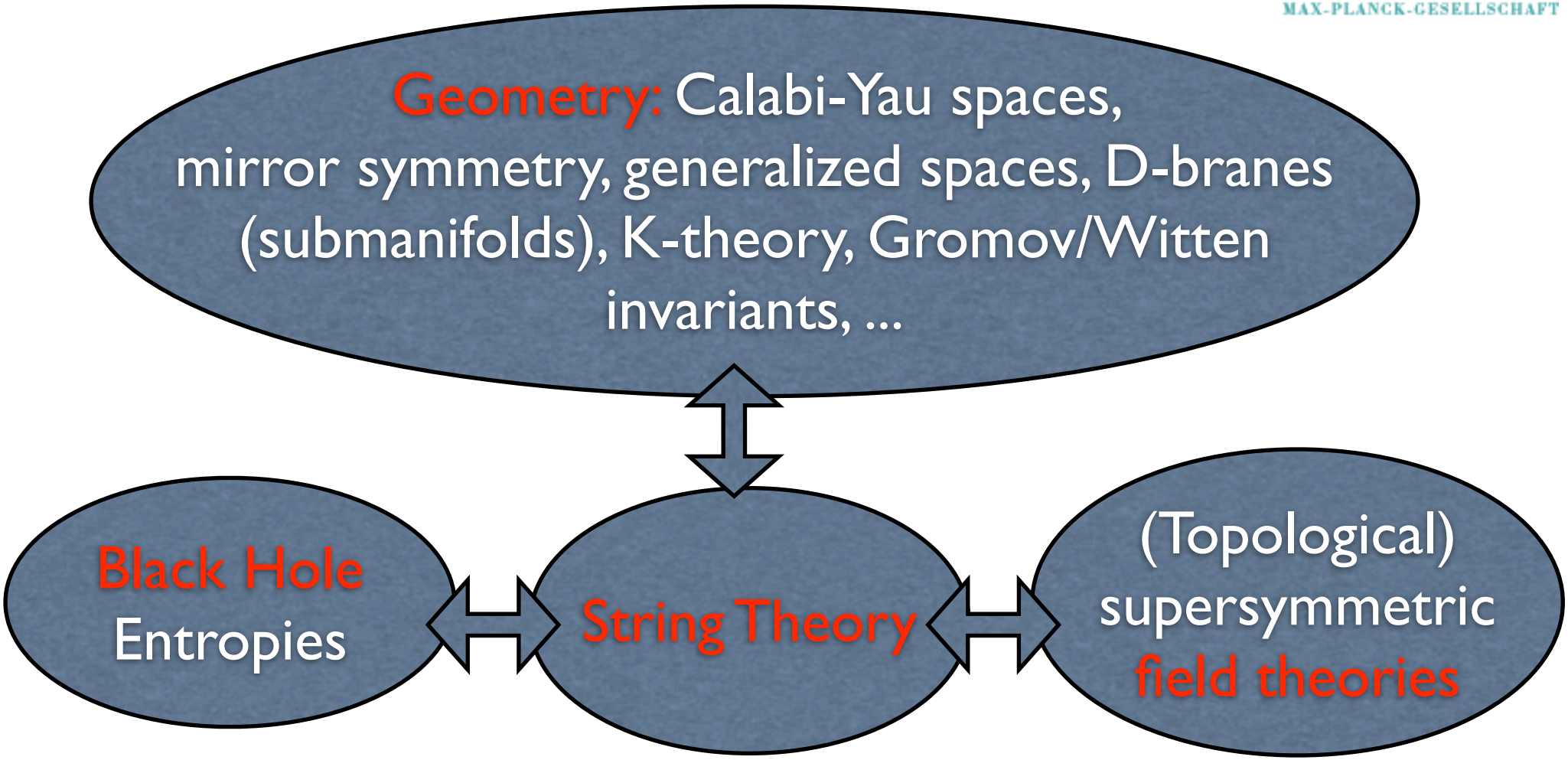

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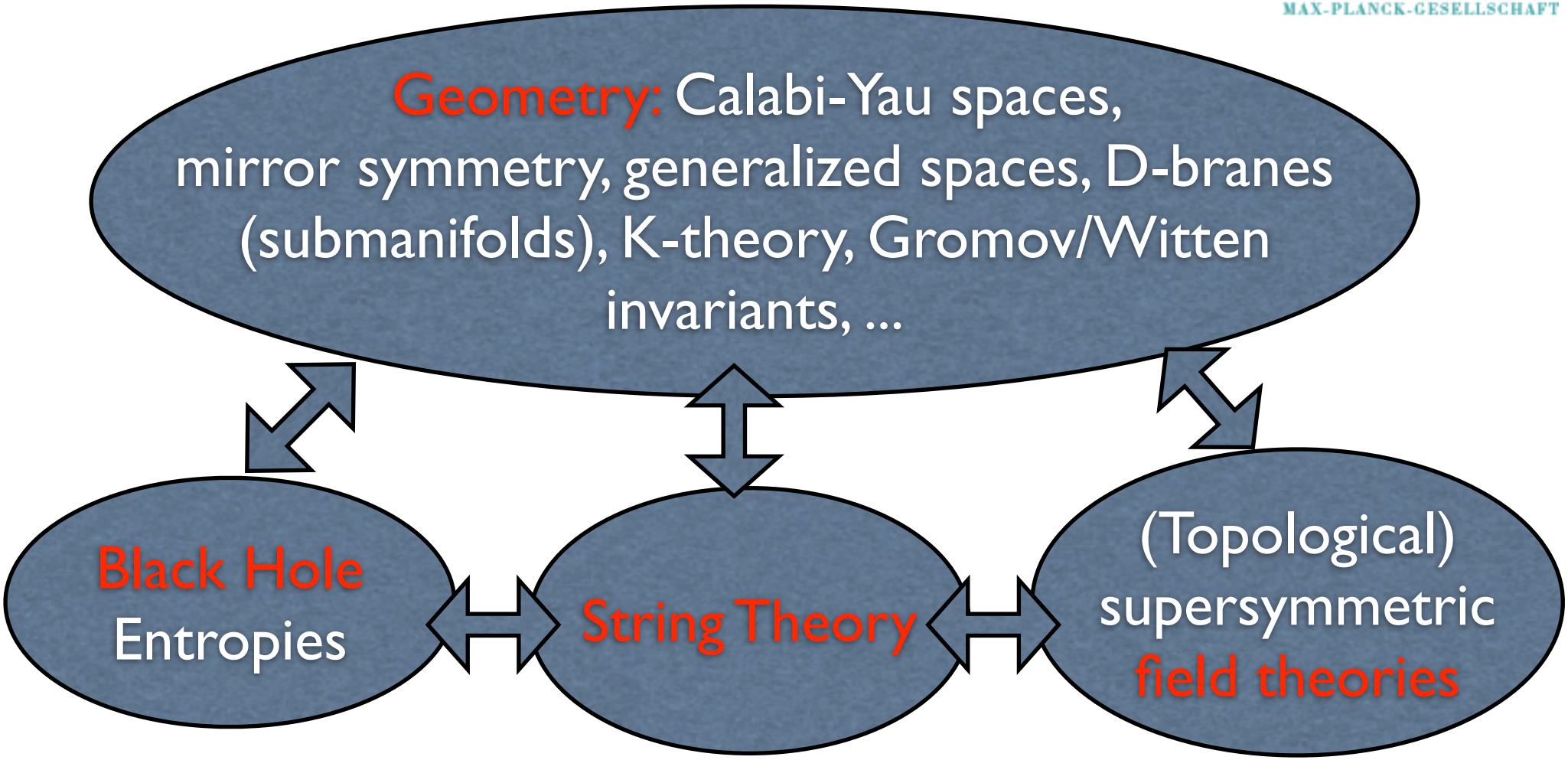

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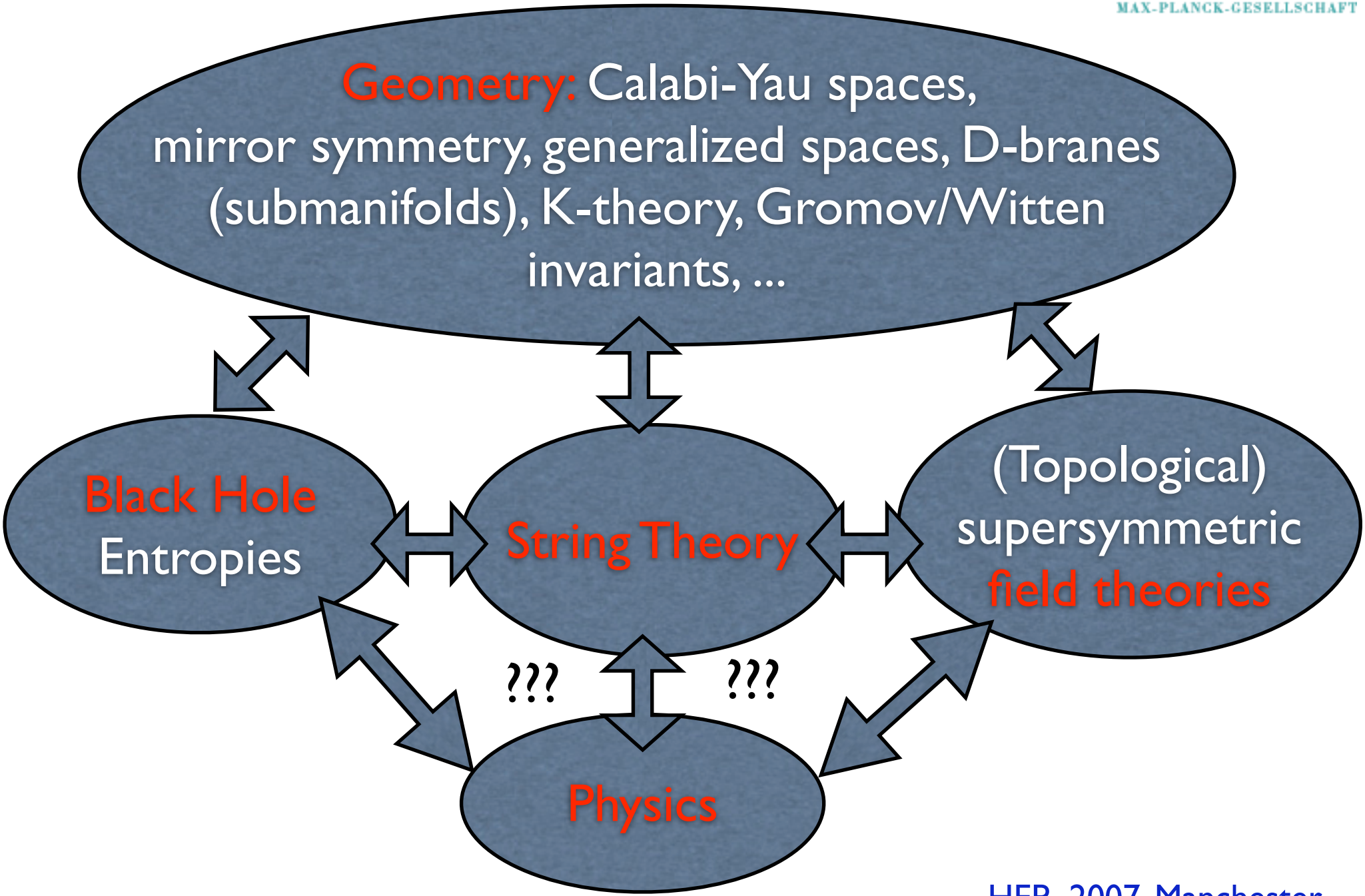

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- ☺ Quantum Gravity

- ☺ Gauge Interactions

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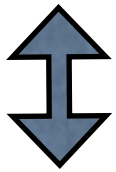

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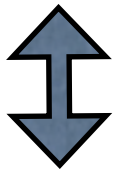

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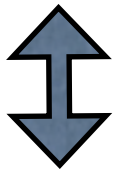

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with 3 generations of quarks and leptons

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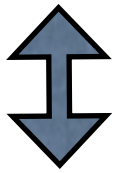

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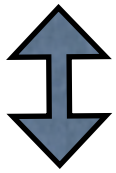

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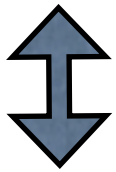

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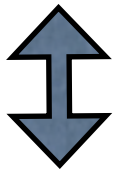

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☛ New testable experimental signatures (extra dimensions, black holes)??

Count the number of consistent string solutions

Vast landscape with $N_{sol} = 10^{500-1500}$ discrete vacua!

(Lerche, Lüst, Schellekens (1986), Douglas (2003))

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Two strategies to find something interesting:

- Explore all mathematically consistent possibilities: top down approach (quite hard), string statistics (perhaps some anthropic point of view is necessary?)
- Do not look randomly - look for green (promising) spots in the landscape ➠ model building, bottom up approach.

Outline

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- Some new results on the AdS/CFT correspondence
  - ☞ Tests
  - ☞ Some steps towards QCD

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(Review: D. Lüst, arXiv:0707:2305)

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II) Some new results on the AdS/CFT correspondence

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D3 branes in 10d

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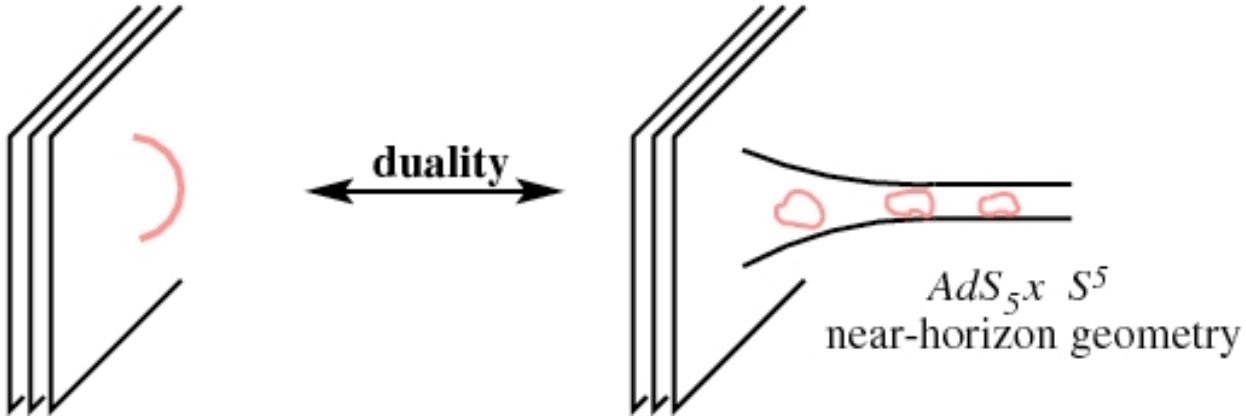
open strings



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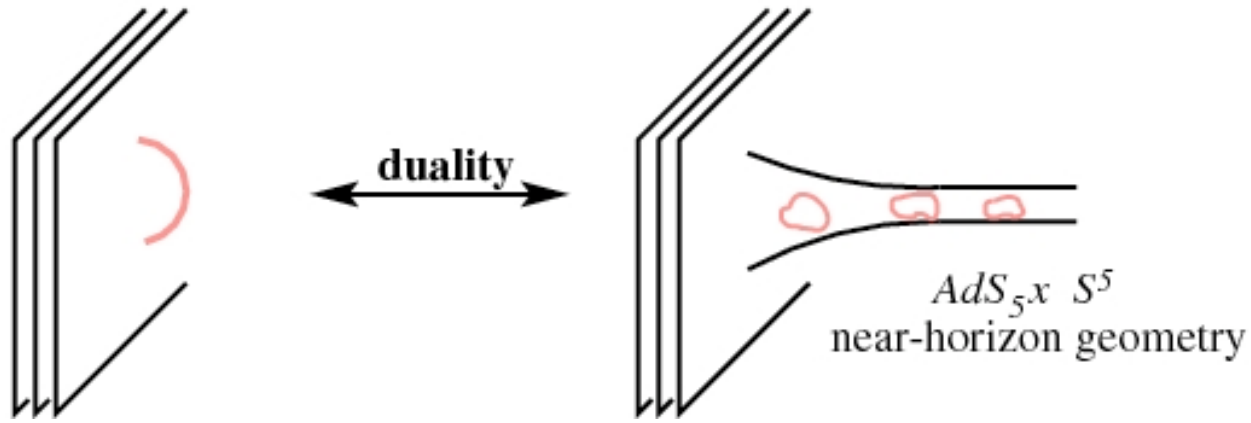

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N=4 supersym. SU(N) gauge theory $\leftrightarrow$ Superstring (supergravity) on $AdS_5 \times S^5$

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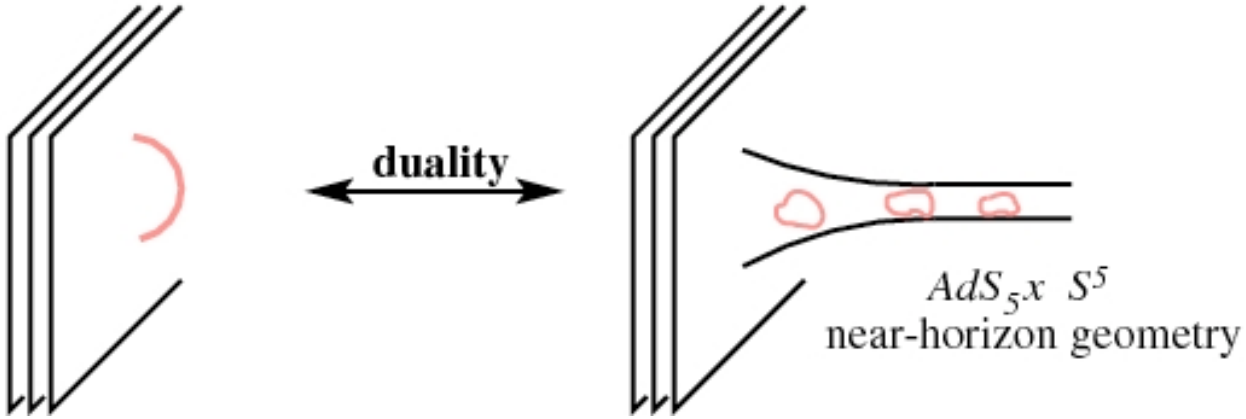

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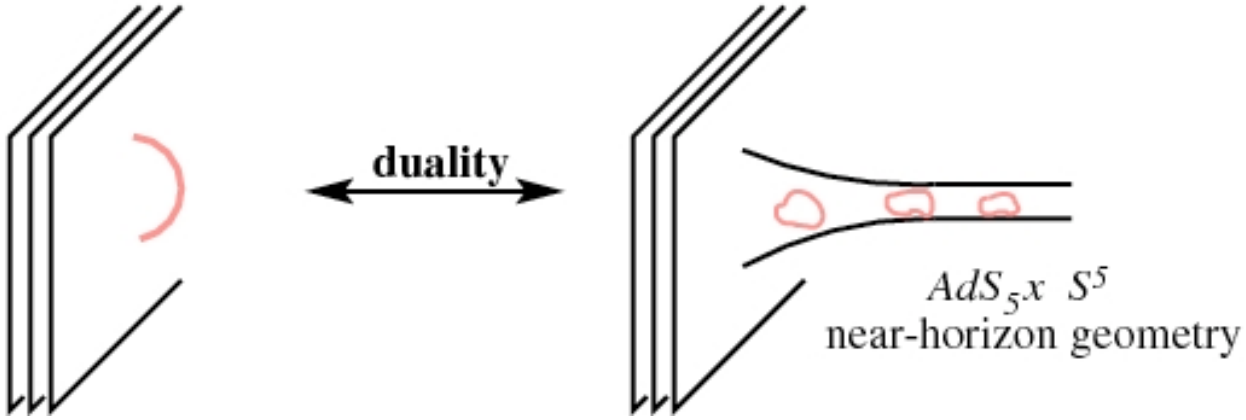

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The correspondence is so far tested for: $N \to \infty,\ \lambda \to \infty$.

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  ☛ Explore universal features!

  (High temperature QCD)

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Consider the anomalous dimension of twist-2 operators:

$$\mathcal{O} = \mathrm{Tr}[(\Phi^k (D\Phi)^l] + \dots , \quad < \mathcal{O}(x)\mathcal{O}(0) >= C|x-y|^{-2\Delta} .$$

$$\Delta = S + f(g)\log(S) + \dots , \quad g^2 = \frac{\lambda}{16\pi^2} \quad \text{(spin chain!)}$$

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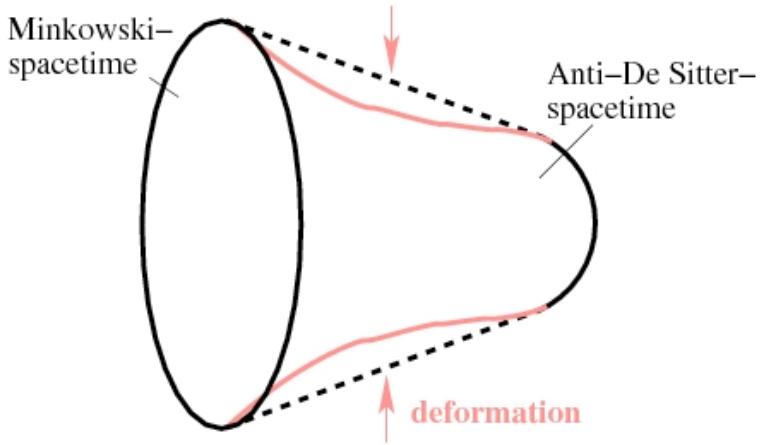
➢ Break supersymmetry and conformal symmetry:

Deformation of AdS-space:



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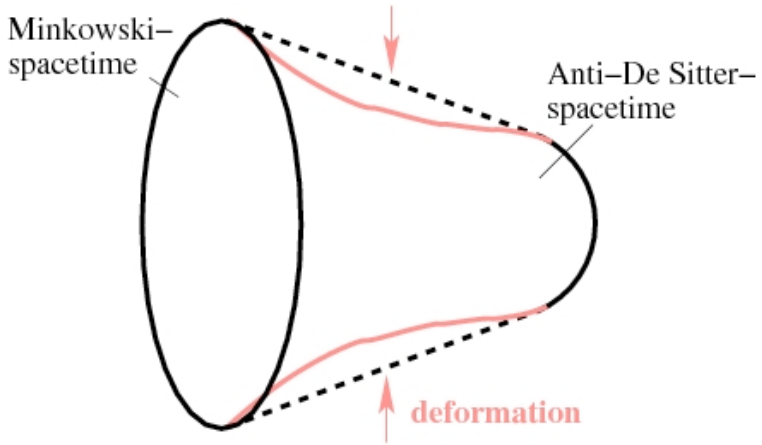
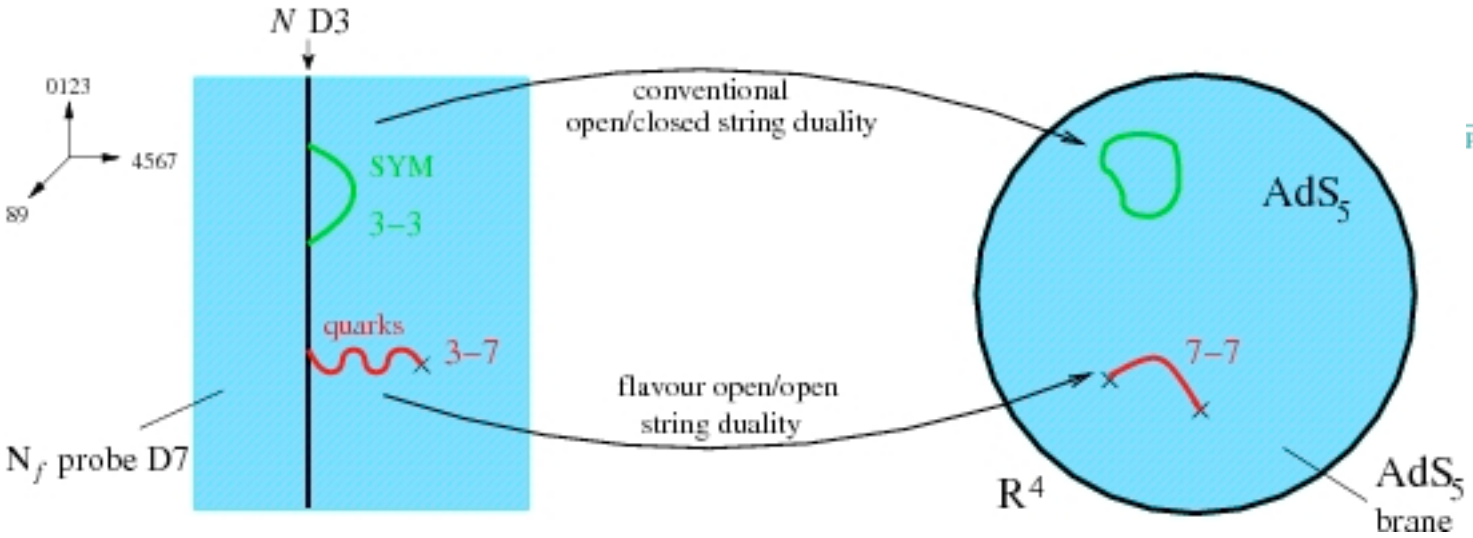


➢ Add quark flavor fields in fundamental repr. of SU(N):

Include D7-branes: Quarks are open strings, stretched between D3- and D7-branes.


N D3
0123
4567
89
SYM
3–3
quarks
3–7
N$_f$ probe D7
conventional
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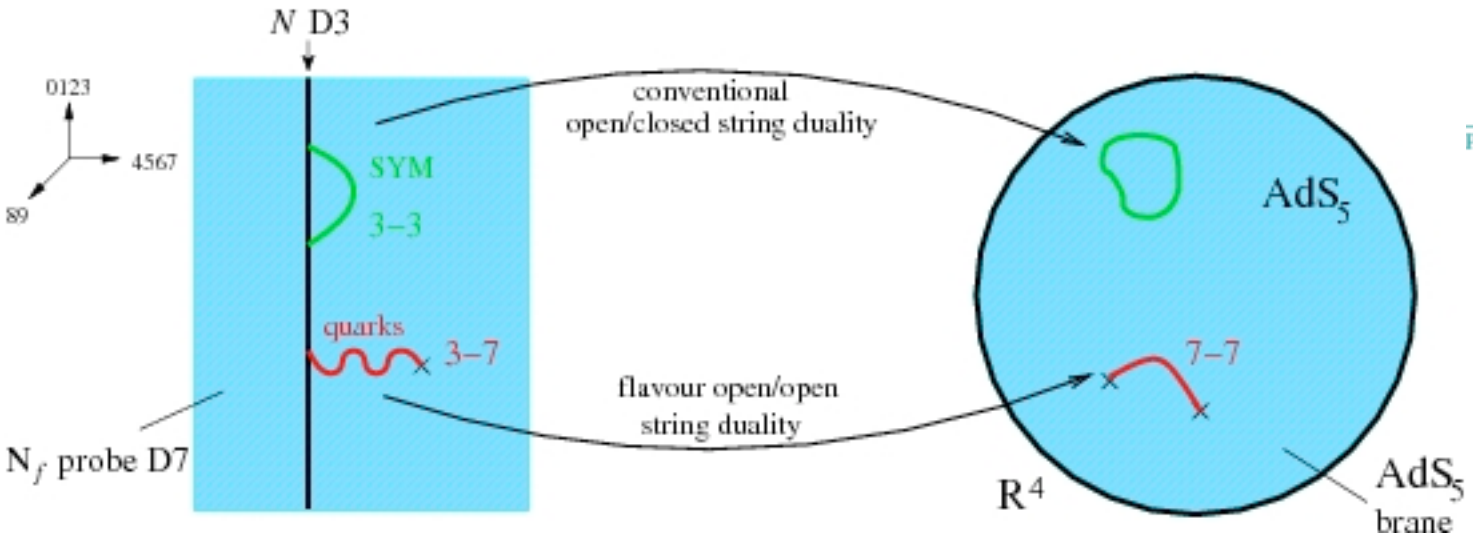

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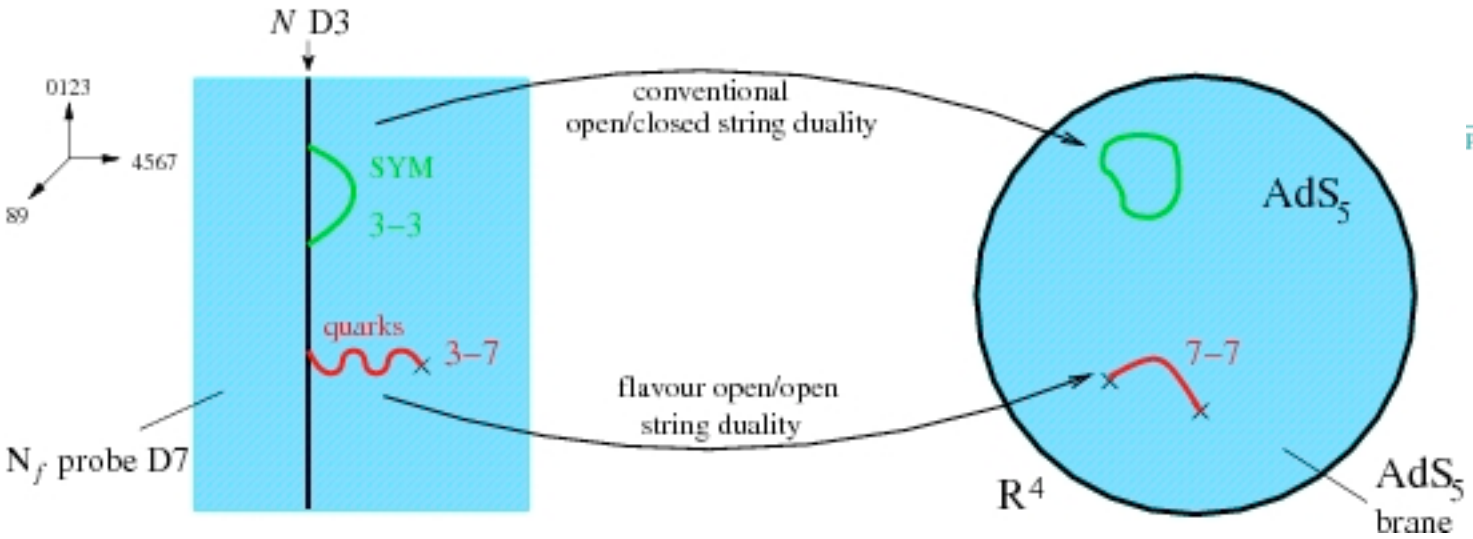

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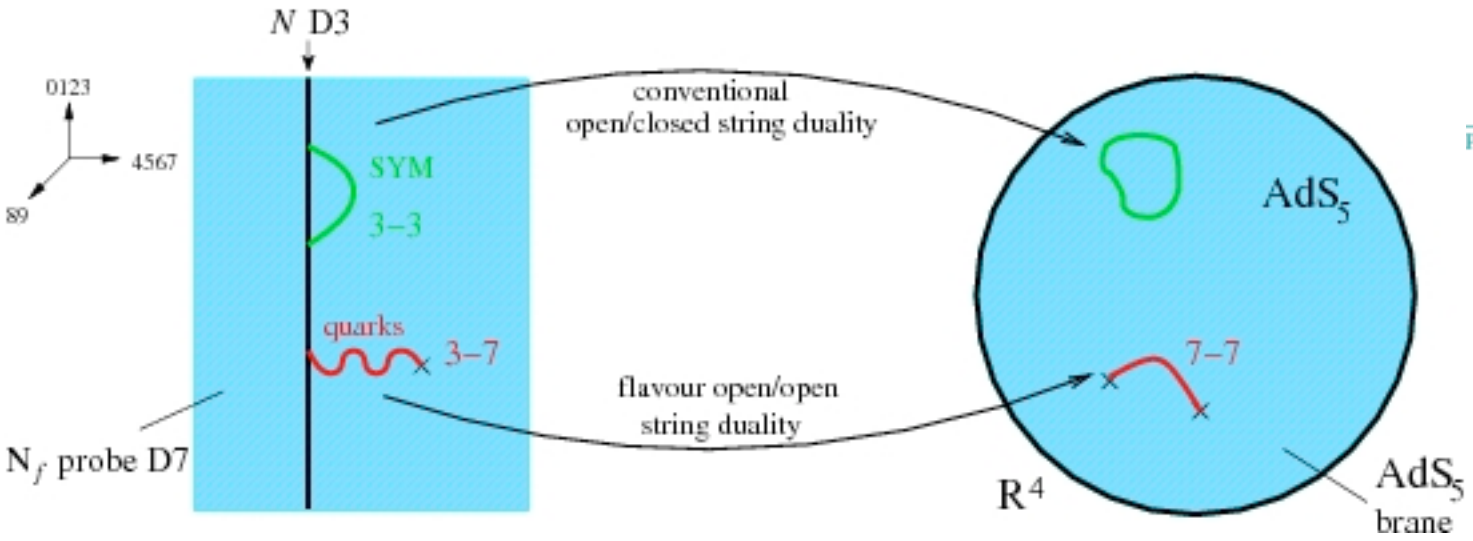

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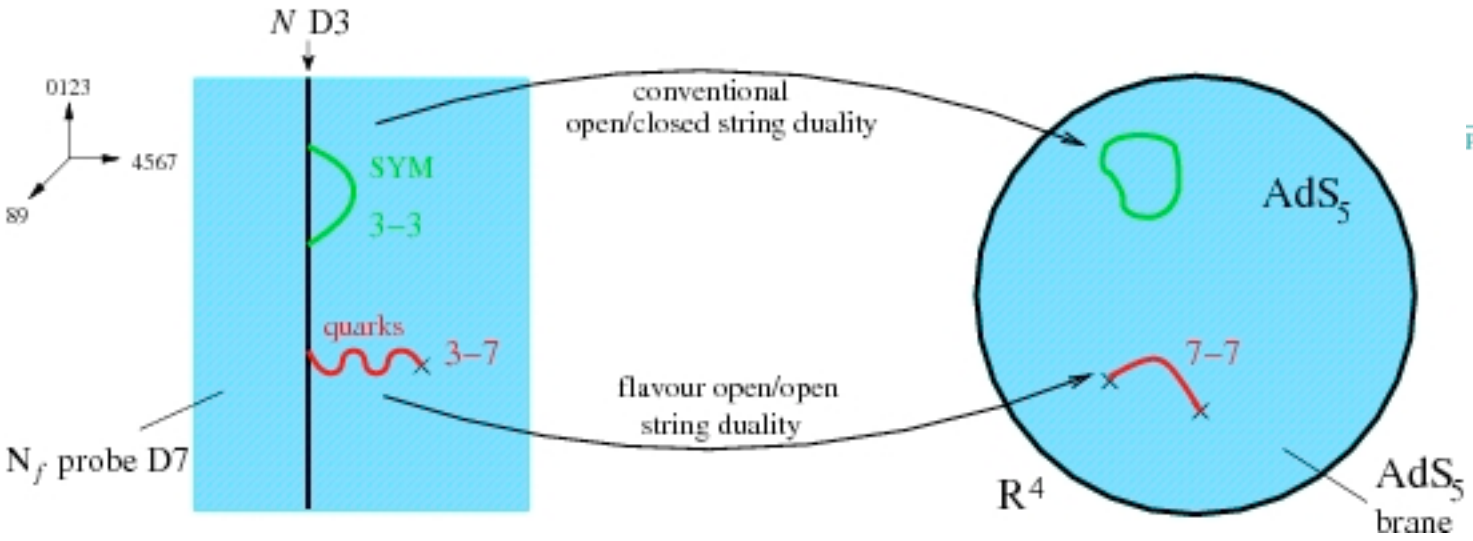
- Compute meson masses: Light Goldstone boson η'

Heavy (axial) vector bosons: $\frac{m_{a_1}^2}{m_\rho^2} \simeq 2.4\,(2.5\,\text{exp.})$



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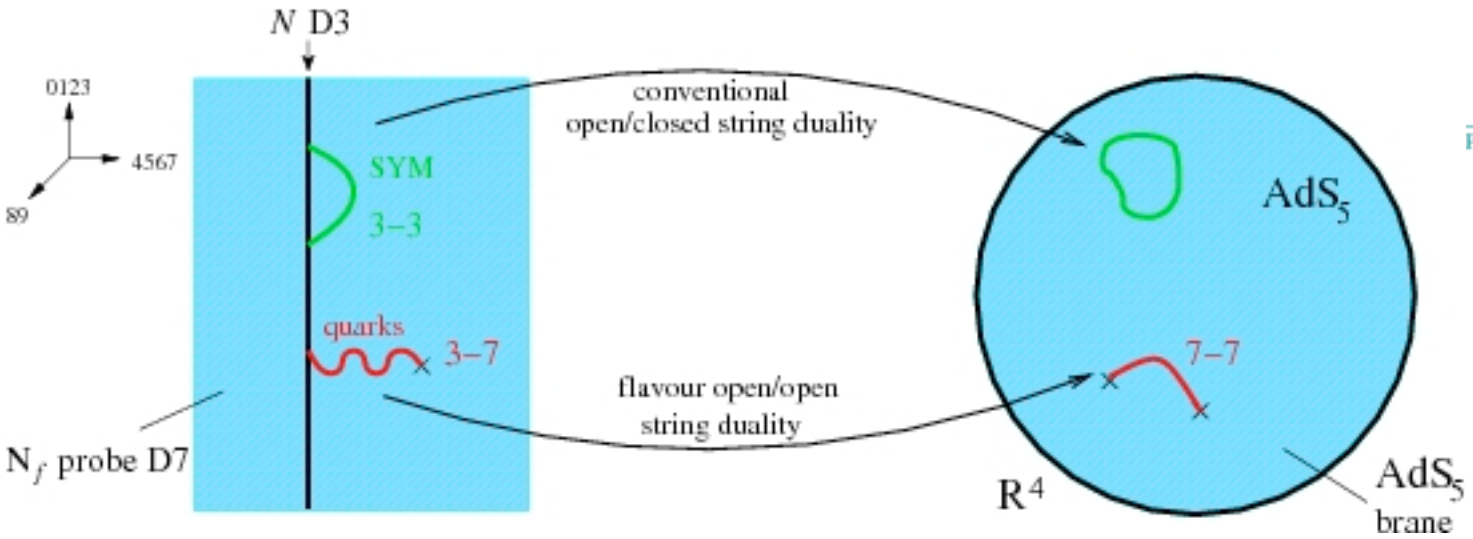

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- Alternative models: D4/D8-branes

(Sakai, Sugimoto (2004/05); Antonyan, Harvey, Kutasov (2006))

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More realistic models: Inclusion of quarks via D7-branes.

(Mateos, Myers, Thomson (2006))

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MAX-PLANCK-GESELLSCHAFT

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- 3-loop Finiteness of N=8 supergravity!

(Bern, Dixon, Roiban (2006))

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  - ☞ Some steps towards QCD
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- Type II orientifolds models

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☹ Moduli stabilization (bundle moduli!) with H-flux is difficult.

(Strominger (1985), Becker, Becker, Dasguta, Green (2003); Curio, Cardoso, Dall'Agata, Lüst, Krause (2003/04/05); Braun, He, Ovrut (2006))

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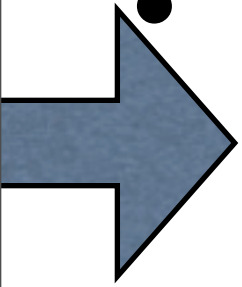

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- Can be combined with background fluxes ➠ moduli stabilization (GKP) and dS-vacua (KKLT)

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(diophantic equations with finite no. of solutions!)

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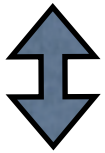
Geometrical, large radius regime:

IIA: special lagrangian submanifolds: D6 on 3-cycles at angles



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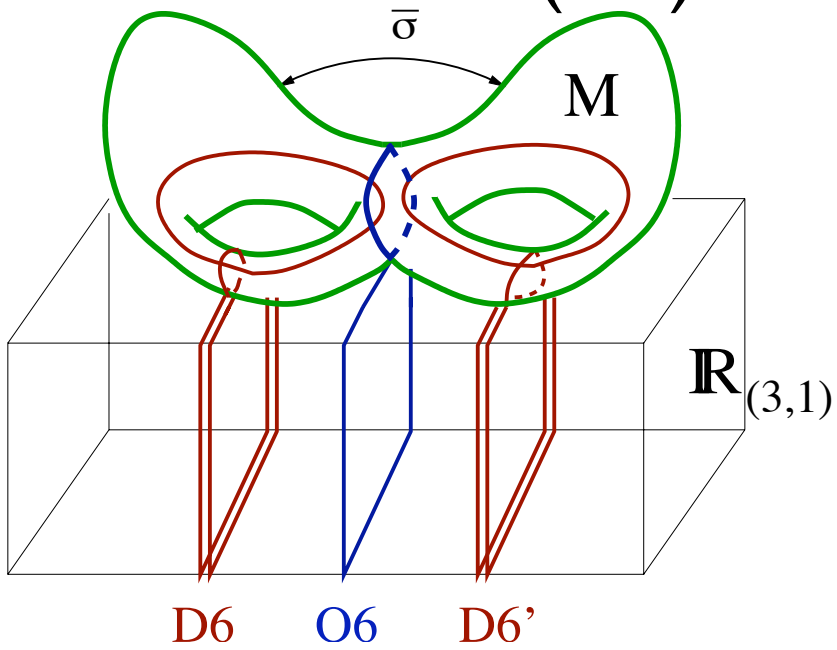

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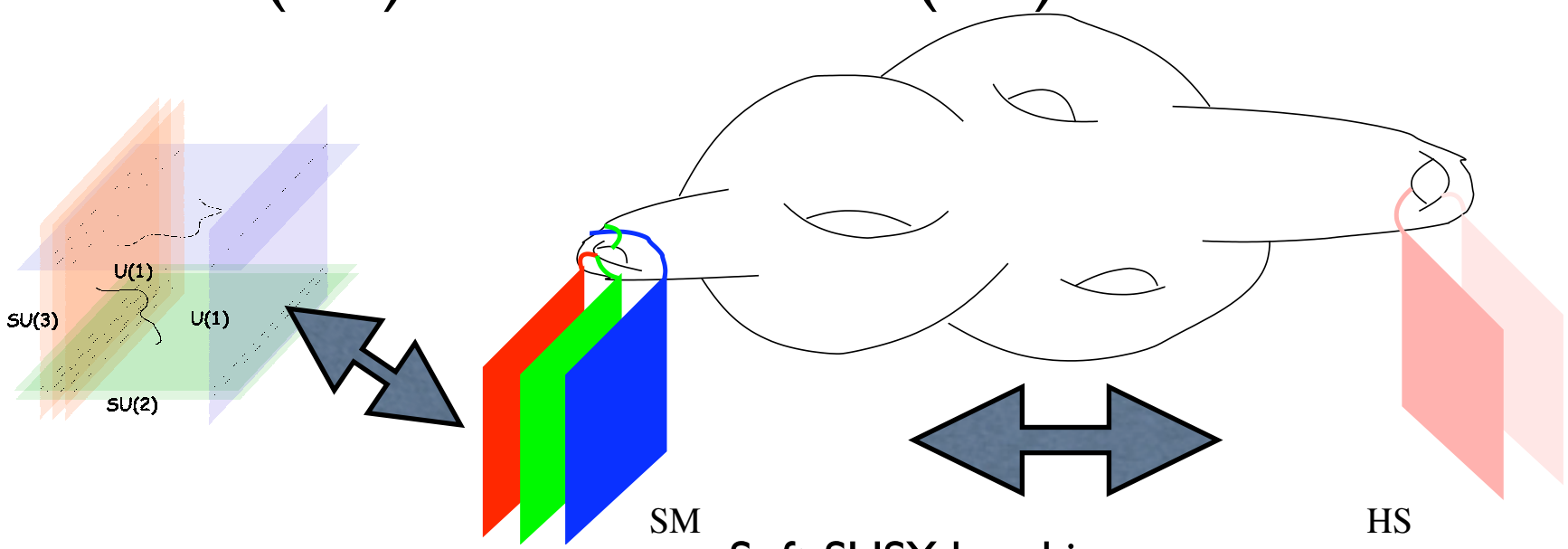

Soft SUSY breaking

(Intersecting) D-brane statistics

How many orientifold models exist which come close to the (spectrum of the) MSSM?

(Blumenhagen, Gmeiner, Honecker, Lüst, Stein, Weigand, hep-th/0411173, hep-th/0510170, hep-th/0703011; related work: Dijkstra, Huiszoon, Schellekens, hep-th/0411129; Anastasopoulos, Dijkstra, Kiritsis, Schellekens, hep-th/0605226; Douglas, Taylor, hep-th/0606109; Dienes, Lennek, hep-th/0610319)

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There exist about $1.66 \cdot 10^8$ susy D-brane models on this orbifold (with restricted complex structure)!

(Finiteness of models was recently proven by D.T.)

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No symmetric representations	0.839
Massless $U(1)_Y$	0.423
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Only one in a billion models gives rise to a MSSM like vacuum!

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- Explicit D-brane constructions:
  there exist many models that come close to the MSSM.
  Problem of exotic particles!

(Chen, Li, Mayes, Nanopoulos, hep-th/0703280; Chen, Li, Nanopoulos, hep-th/0604107; Blumenhagen, Plauschinn, hep-th/0604033; Bailin, Love, hep-th/0603172; Blumenhagen, Cvetic, Marchesano, Shiu, hep-th/0502095; Marchesano, Shiu, hep-th/0409132; Honecker, Ott, hep-th/0407181; .....)

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  - ☞ Some steps towards QCD
- Heterotic string compactifications
- Type II orientifolds models

  Intersecting brane models and their statistics

  D-instantons: non-perturbative couplings
- Outlook: Prospects for the next years

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Take into account non-perturbative instanton corrections to the effective action!

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- Can generate new matter couplings (Majorana masses, Yukawa couplings) → see in a moment.

LMU

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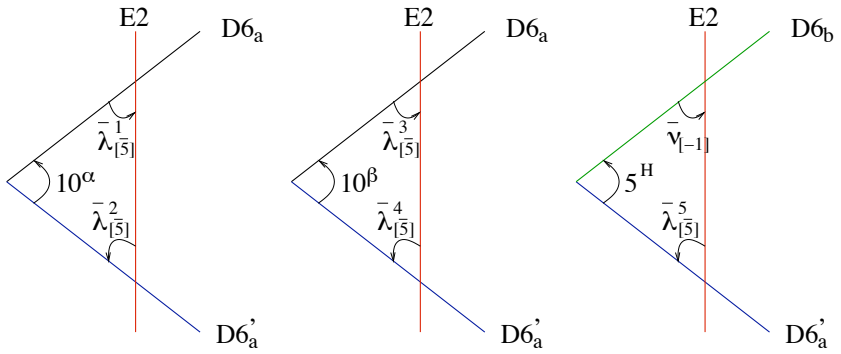

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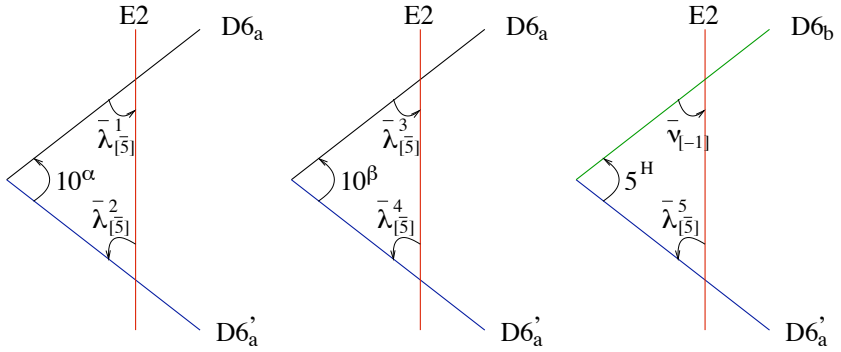

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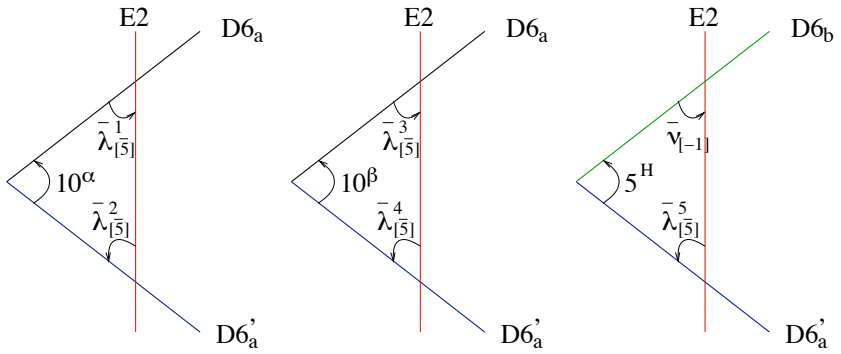

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E2-instantons also relevant for doublet-triplet splitting, Majorana masses, masses for exotic states, ...

(Ibanez, Uranga, hep-th/0609213; Cvetic, Richer, Weigand, hep-th/0703028; Ibanez, Schellekens, Uranga, arXiv:0704.1079; Antusch, Ibanez, Macri, arXiv:07062132; Bianchi, Kiritsis, arXiv:0702015; Bianchi, Fucito, Morales, arXiv:0704.0784)

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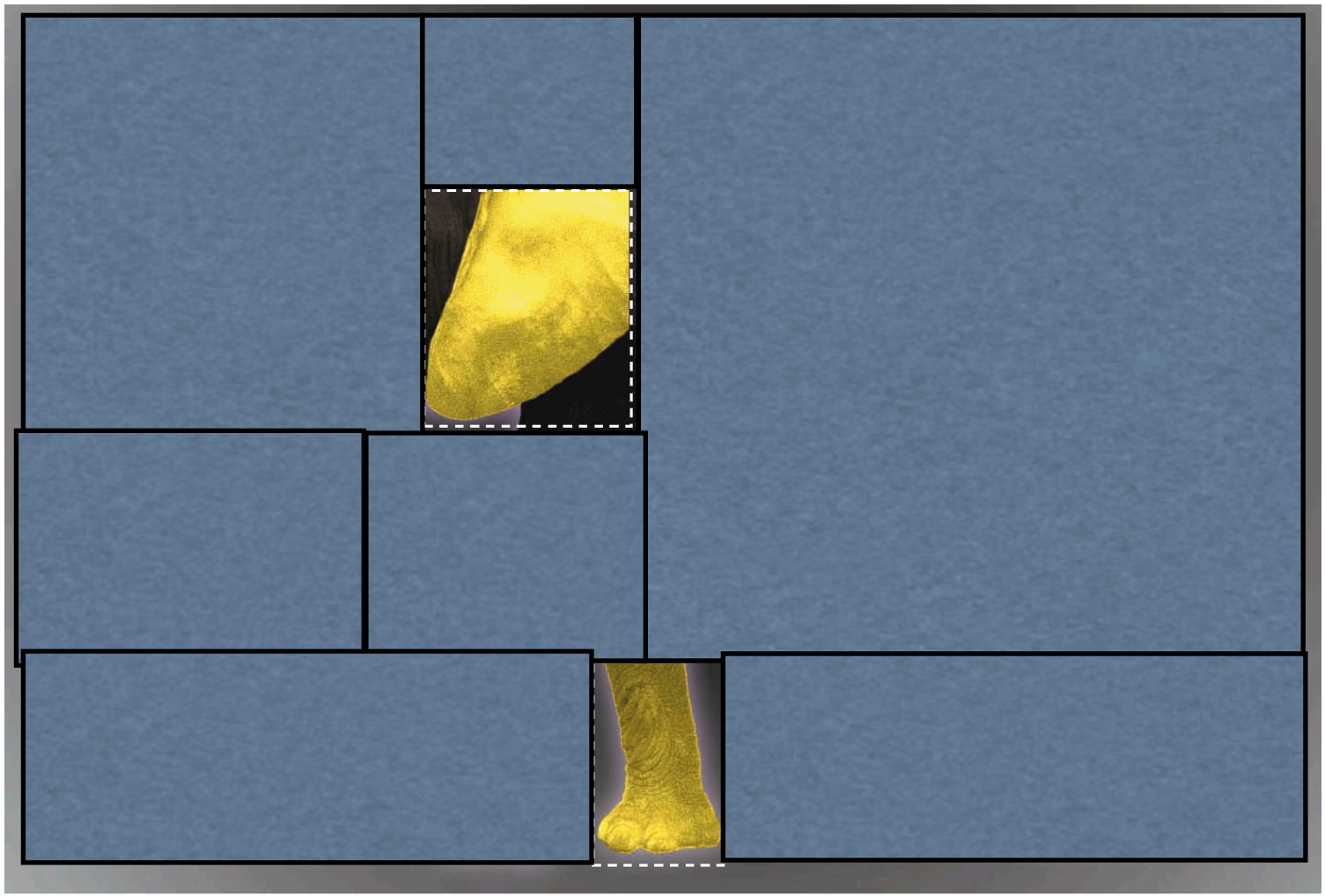

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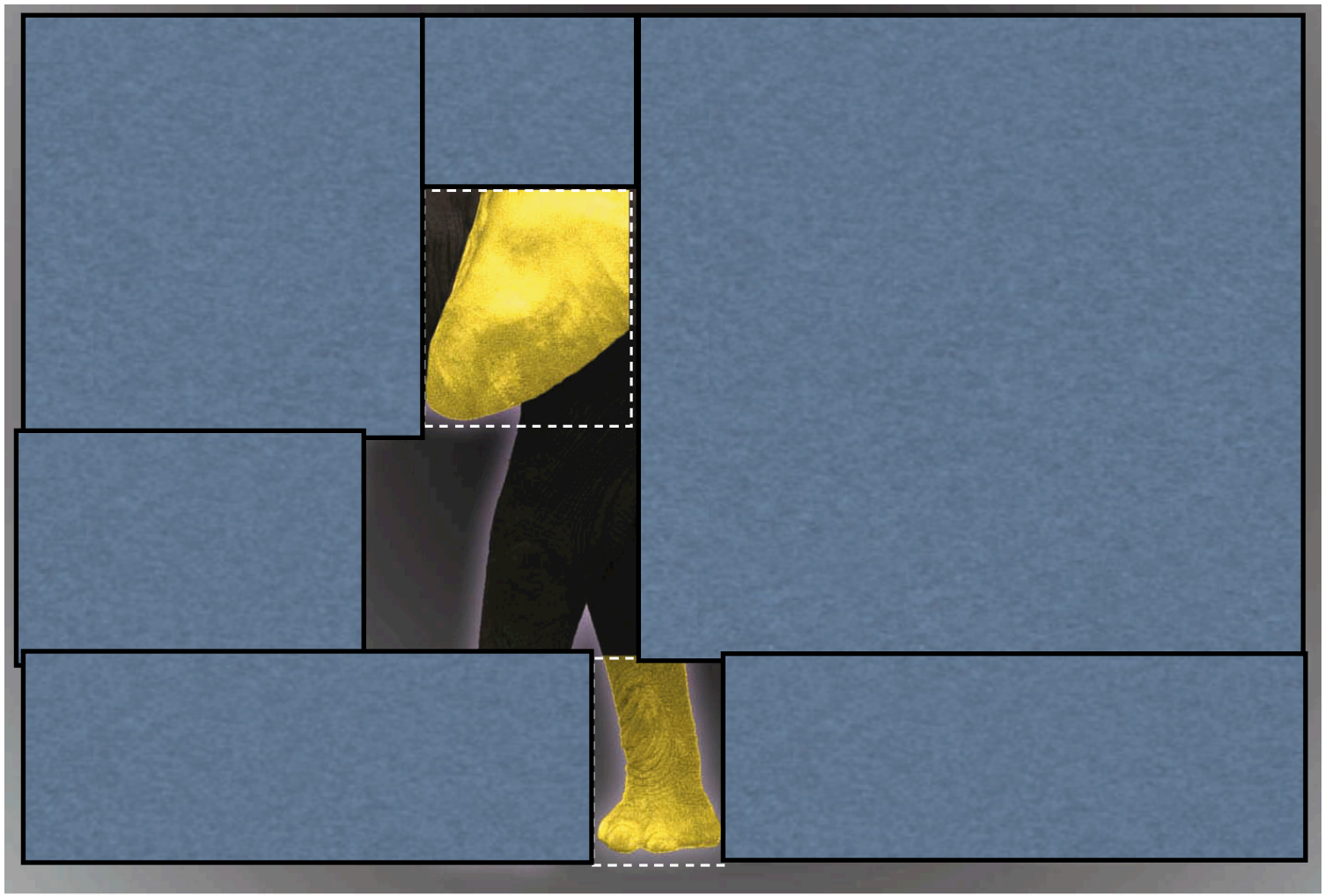

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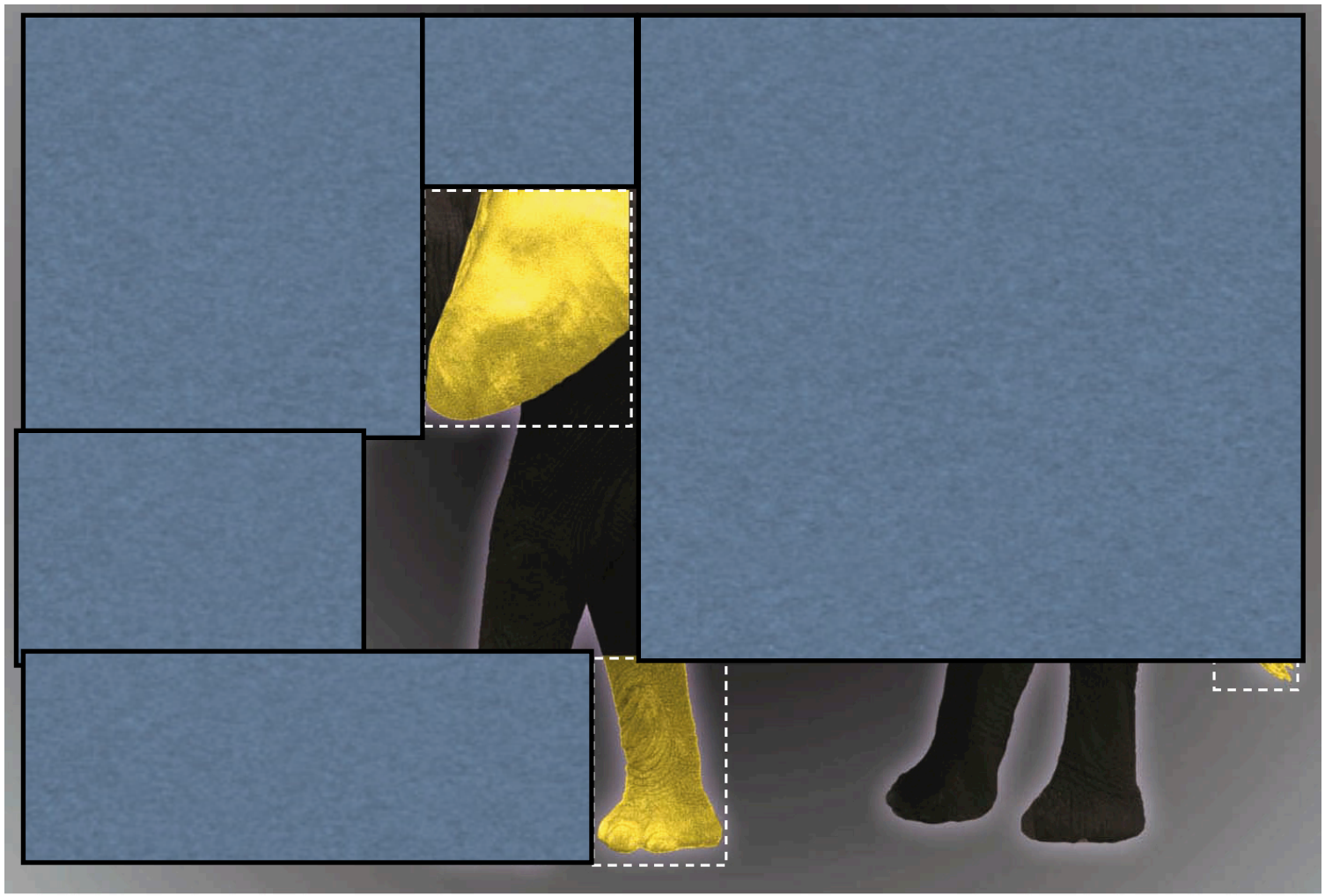

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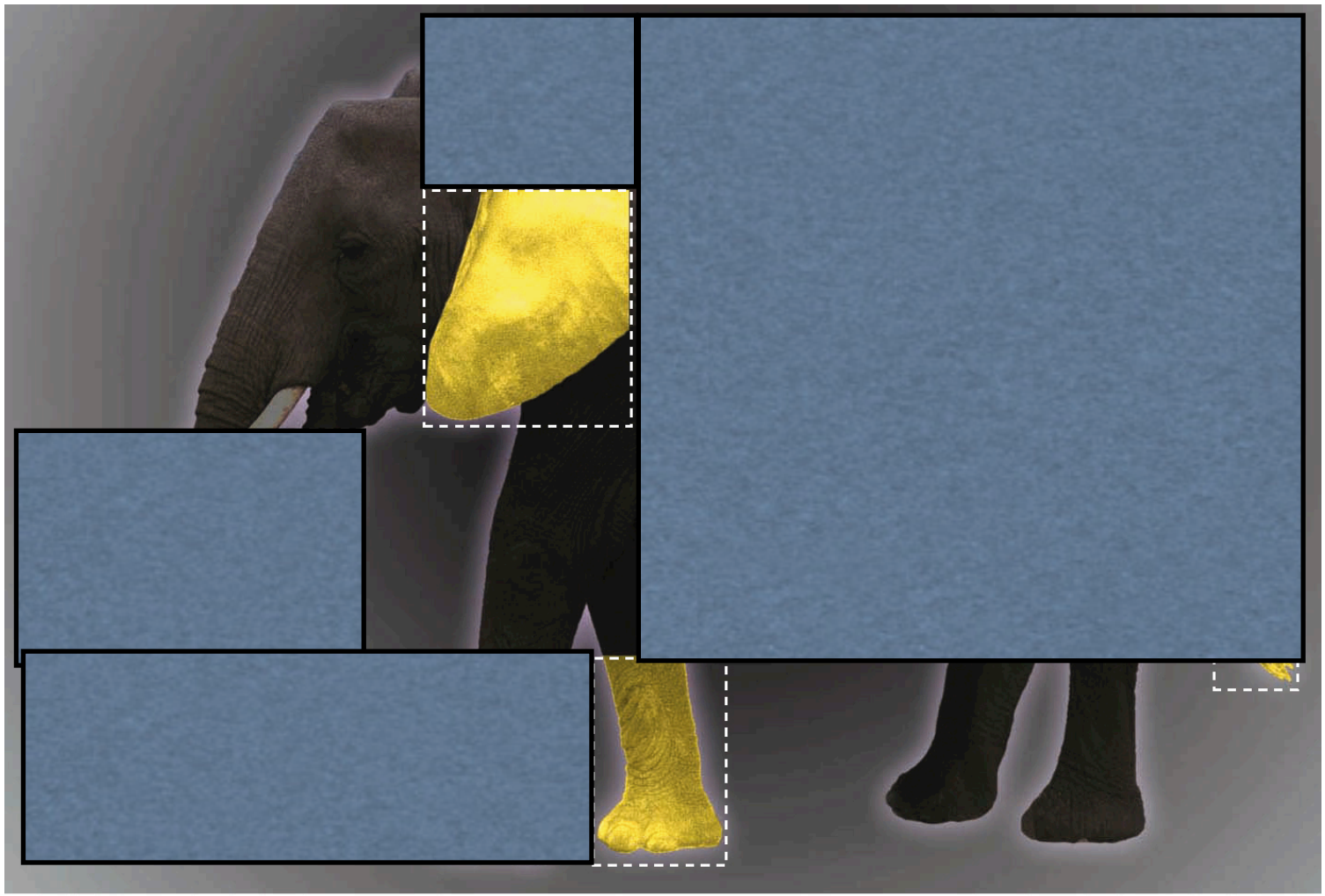

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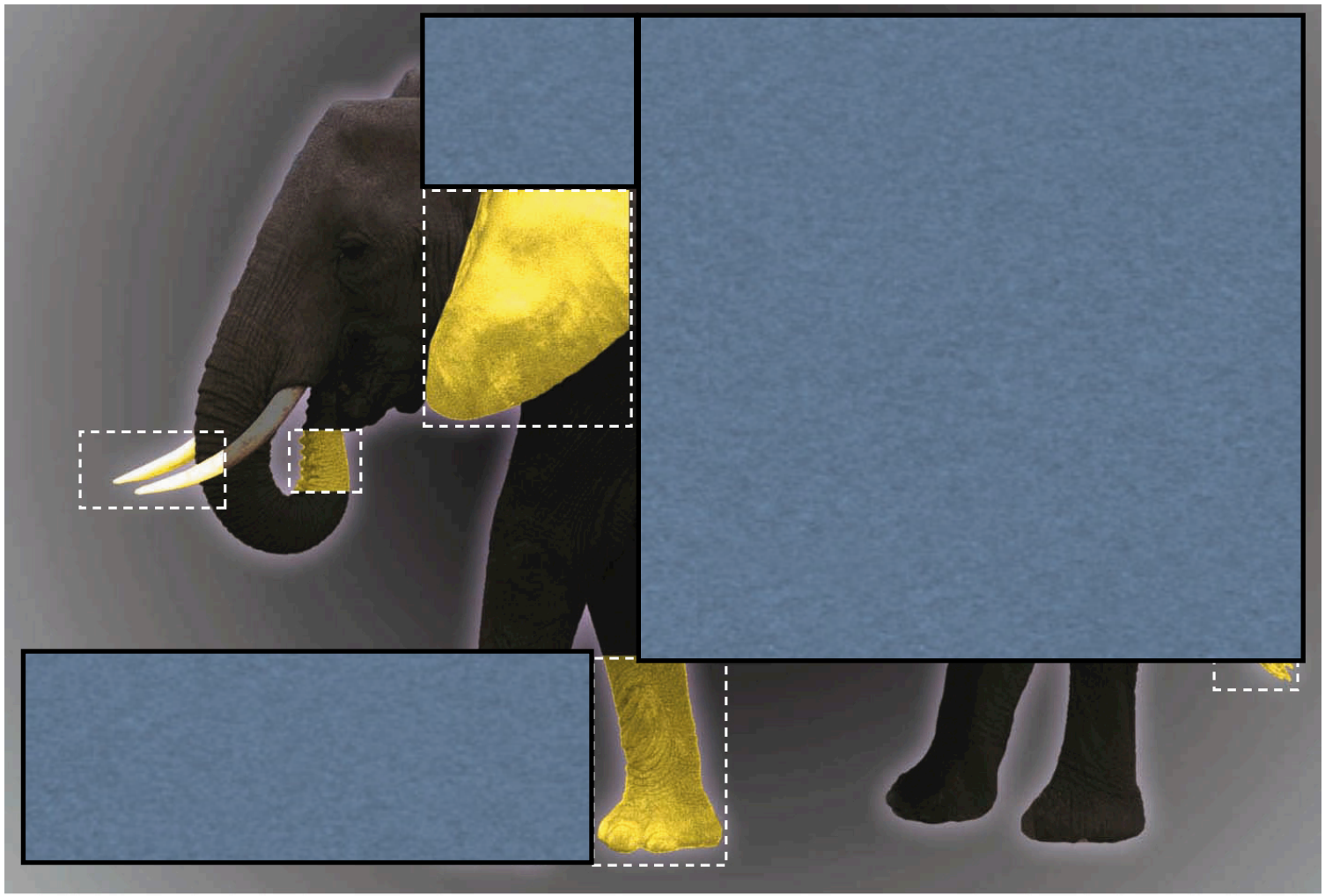

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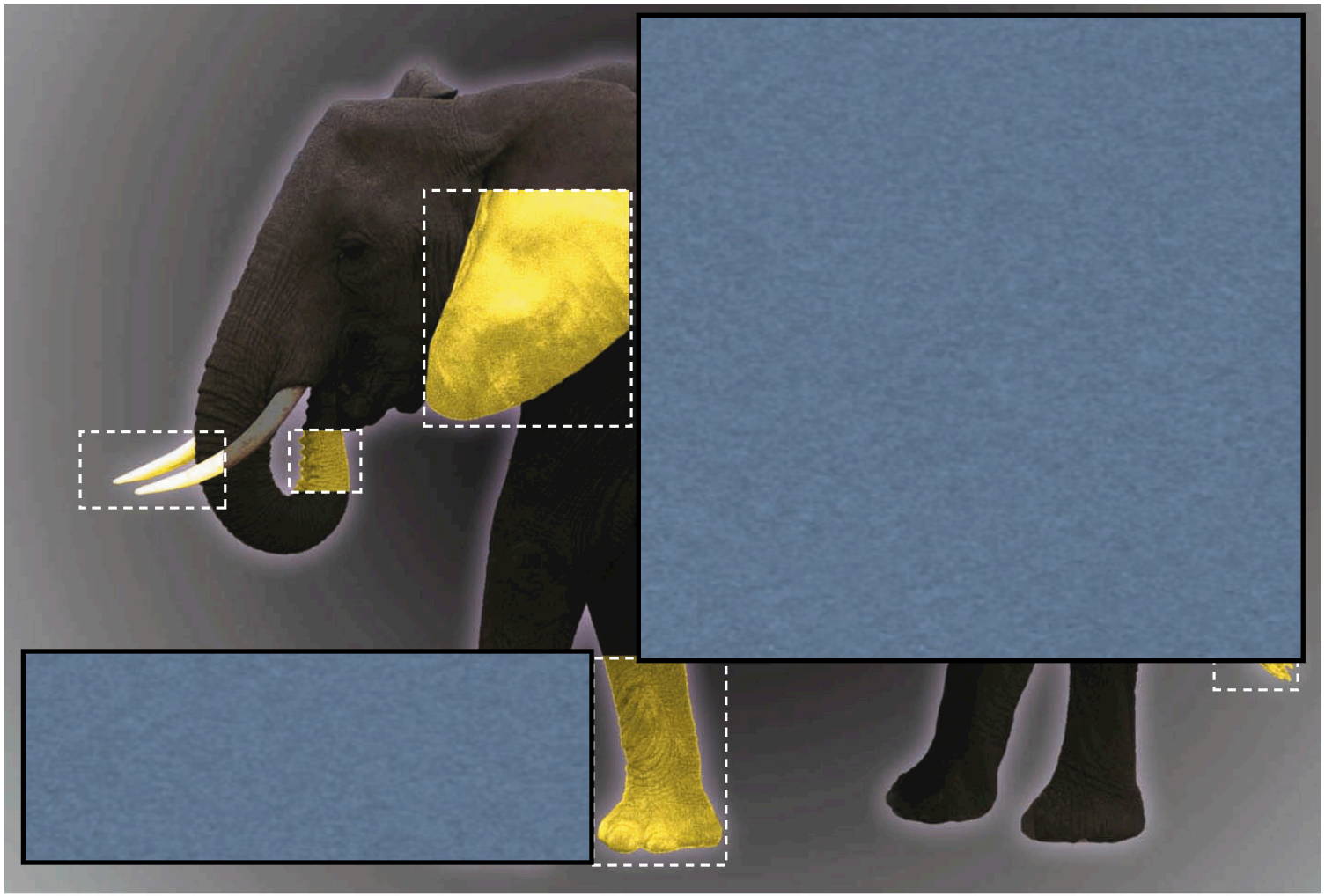

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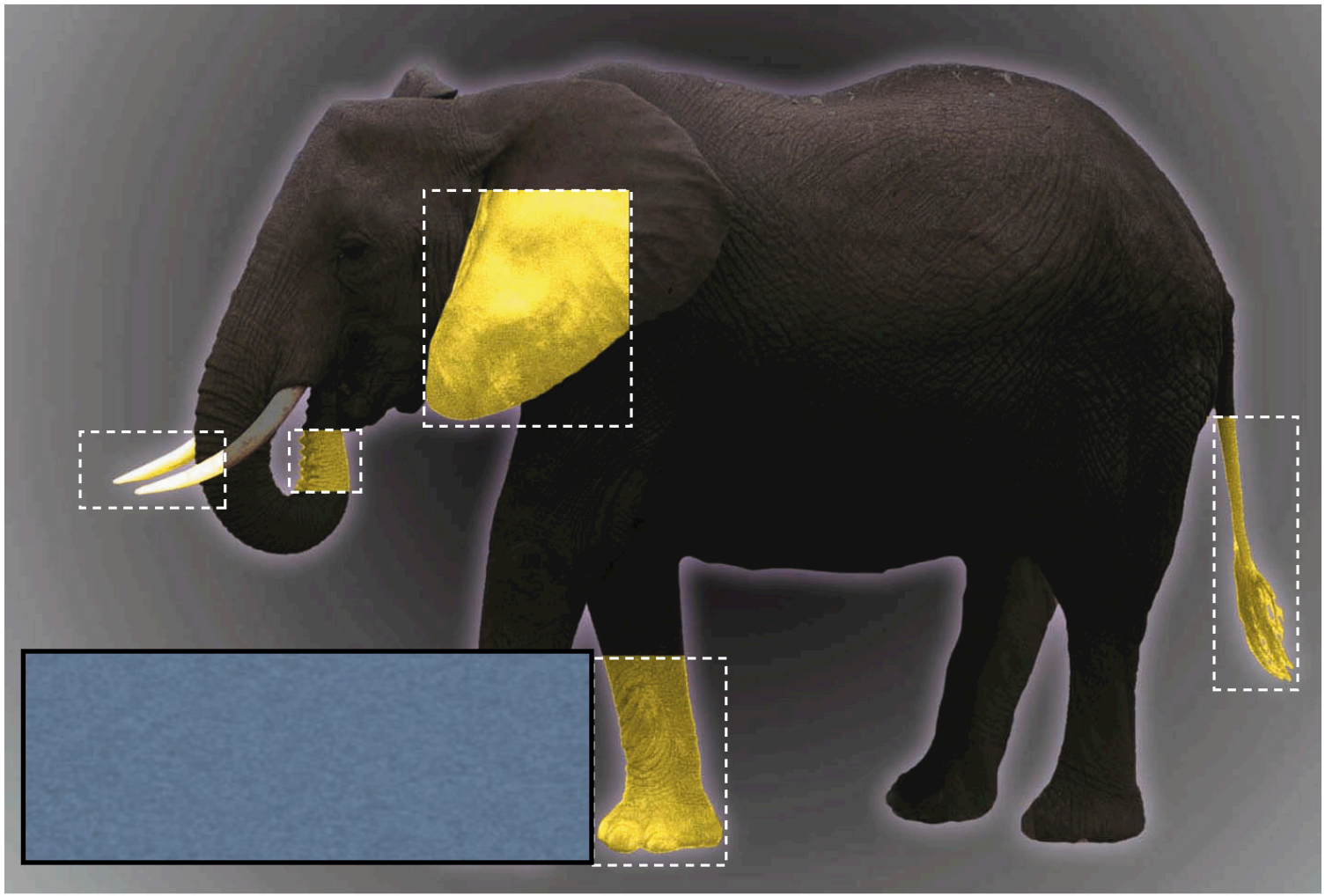

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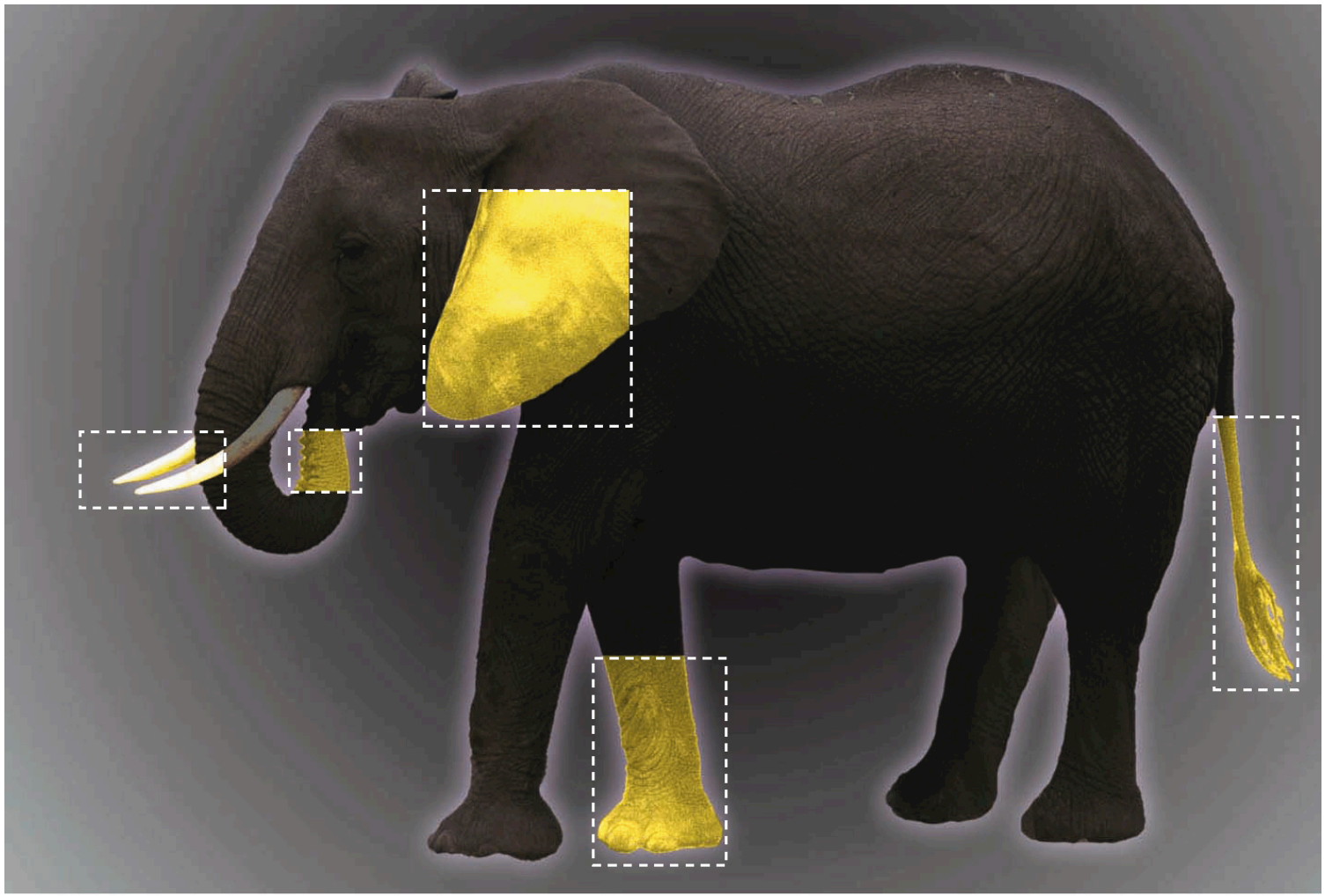

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