École de Physique des Houches

Research Interests & Scientific Activities

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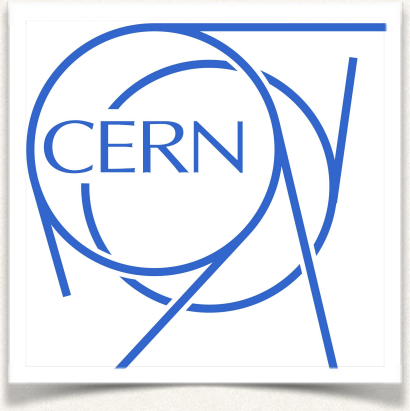


CERN Theory Group Retreat 2015

5th of November, 2015

My background & research interests in short

Background:

- PhD in 2011 from universitätbonn.
- Postdoc 2011-2014 at Penn University of Pennsylvania.
- Fellow at CERN since September 2014.

Research field:

String Phenomenology broadly defined.

- Development of techniques to determine effective physics of String Theory.
- Work at interface between physics/mathematics.

Obtaining the effective physics of string theory

Goal: obtain all data of effective theories from data of UV theory for

- String Phenomenology: particle physics, cosmology… . (focus of my talk)
- study of dynamics of strongly coupled QFTs with new tools.

Problems:

1. Many solutions, so called **vacua**, of string theory.
2. solutions rich & very complicated.

➡ Need formulation of String Theory that allows to construct large set of string vacua & provides powerful tools to extract physics.

F-theory: all string vacua & duality techniques

F-theory is paradigm framework:

1. describes many vacua of String Theory

- evidence that it realizes all known effective theories of String Theory,
- ingredients to produce promising particle physics models & cosmology

2. provides duality techniques to control complicated physics

- Strong/weak duality (S-duality): $g_S \longrightarrow 1/g_S$
- Geometrisation = translation between

Effective theories ⟷ Physics Geometry ⟷ Calabi-Yau (CY) geometry

➡ control physics by powerful tools in geometry.

F-theory: string coupling & branes to geometry

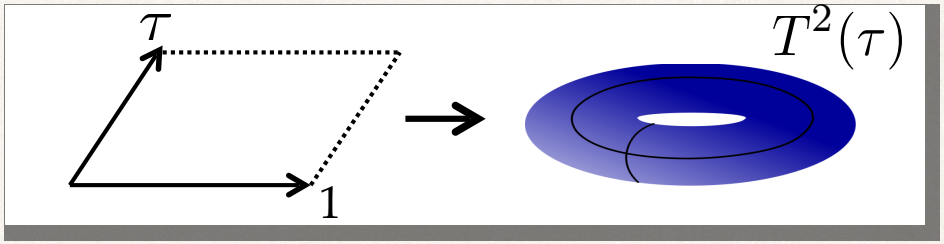
F-theory = Duality + Geometrisation in Type IIB String Theory.

- Type IIB has S-duality acting on complexified string coupling $\tau = ig_S^{-1} + C_0$ as Dehn-twist

$$\tau \mapsto \frac{a\tau + b}{c\tau + d} \qquad \text{with} \qquad \begin{pmatrix} a & b \\ c & d \end{pmatrix} \in \mathrm{SL}(2,\mathbb{Z})$$

- Natural object to consider is not τ: find $\mathrm{SL}(2,\mathbb{Z})$-"gauge-invariant" object

➡ two-torus T^2:



- Two-torus $T^2(\tau)$ is invariant under S-duality action on τ

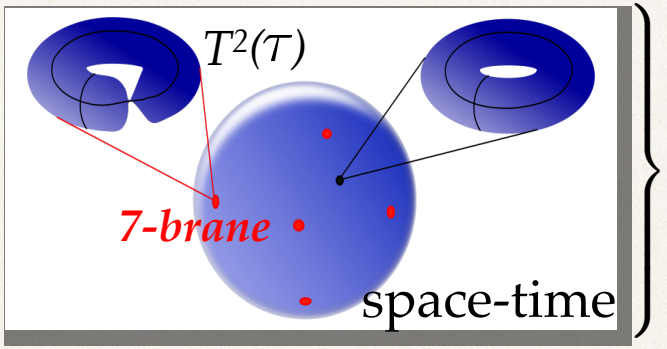
➡ S-duality invariant description requires replacing τ by geometry $T^2(\tau)$

F-theory: string coupling & branes to geometry

Important: $\tau = ig_S^{-1} + C_0$ is dynamical field in String Theory

- Non-trivial field profile of τ ➡ $T^2(\tau)$ varies over space-time.
- sources of τ are 7-branes at which $|\tau| \to \infty$

➡ singular $T^2(\tau)$ signals 7-brane



➡ change of perspective:
X defines manifold

➡ 7-branes replaced by geometry: singularities in X

- Interesting vacua of string theory constructed if X is Calabi-Yau manifold

Effective physics from geometry

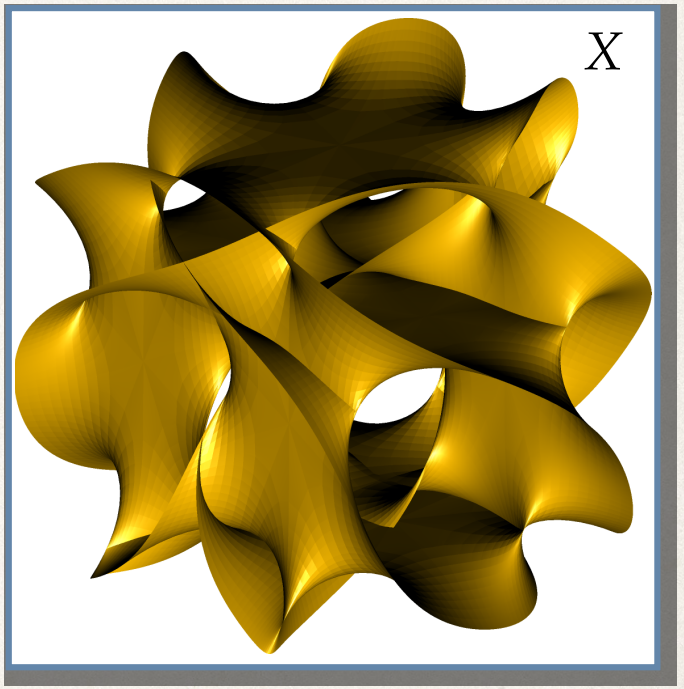
Physics of 7-branes
in IR: interesting effective theories in 4D (6D)

Physics/Geometry

geometry of Calabi-Yau manifold X

1. Gauge group
2. Matter sector
3. Coupling functions

Physics/Geometry



My research: geometric techniques for physics/geometry dictionary

Effective physics from geometry

Effective Theory	Geometry
1.Gauge group	
✣ non-Abelian part ✔	✣ Singularities in X: classified ✔
✣ U(1) factors & discrete quotients	✣ Mordell-Weil group of elliptic fibrations M.Cvetic, A.Grassi, D.K., H.Piragua, P.Song: arXiv:1303.6970, arXiv: 1306.3987, arXiv:1307.6425, arXiv:1310.0463, M.Cvetic, D.K., H.Piragua, W. Taylor arXiv:1507.05954.
✣ discrete gauge group	✣ Tate-Shafarevich group of genus-1 fibrations. D.K.,D.Mayorga-Pena,P.Oehlmann,J.Reuter,H.Piragua arXiv:1408.4808, M.Cvetic,R.Donagi,D.K., H.Piragua, M.Poretschkin arXiv1502.06953
✣ Large gauge transformations	✣ (new) arithmetic structures on ellip. fibrations T.Grimm, A.Kapfer, D.K. arXiv:1510.04281
2. Matter sector	
✣ simple representations ✔	✣ Tate/Weierstrass models for X ✔
✣ higher tensor representations	✣ new non-Tate Weierstrass models for X M.Cvetic,D.K.,H.Piragua,W. Taylor arXiv:1507.05954, D.K., Taylor: in progress
✣ generation of chiral spectrum ✔	✣ background fluxes: conditions & construction of fluxes for new Calabi-Yau manifolds ✔ arXiv:1303.6970,
✣ selection rules for Yukawas ✔	✣ collision of singularities. ✔ arXiv: 1306.3987 arXiv:1310.0463,

number theory

Effective physics from geometry

Effective Theory	Geometry
3. Computing coupling functions	
✣ gauge coupling function	✣ warping in F-theory encodes α'-corrections to gauge coupling T.W.Grimm, D.K., M.Poretschkin: arXiv: 1202.0285
✣ superpotential for moduli fields	✣ fourfold periods computed using differential eq.: determine F-theory flux superpotential. T.W.Grimm, T.Ha, A.Klemm, D.K.: arXiv:0909.2025 T.W.Grimm, T.Ha, A.Klemm, D.K.: arXiv:0912.3250

➡ Application: construction of MSSM, Pati-Salam & trinification models

M.Cvetic, D.K., D.Mayorga-Pena, P.Oehlmann, J.Reuter arXiv:1503.02068

Open questions & future research directions

1. Geometry/Physics:

- Classify all possible gauge symmetries and matter reps in F-theory
- Construct set of F-theory all vacua: moduli space of quantum gravity theory
- Computation of all N=1 coupling functions of chiral 4D F-theory compactifications:
  a) matter couplings unknown.
  b) moduli stabilization & cosmology.
- Engineer & study 6D SCFTs.

2. Conceptual questions:

- Defining data of F-theory: CY X, G_4-flux, Hitchin system on discriminant locus of Calabi-Yau X, T-branes/gluing branes, matrix factorization, generalization of categories… ?
- Microscopics of F-theory: D3-branes, M2-branes, (p,q)-webs…?