Calabi-Yau Compactifications

Challenger Mishra

Collaborators
Prof Andre Lukas, Rudolf Peierls Centre for Theoretical Physics
Prof Philip Candelas, Mathematical Institute

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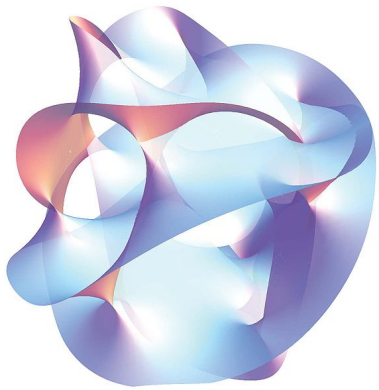
Why Calabi-Yau Compactifications?

- Strings move on a spacetime manifold of the form: $\mathbf{M^4 \times N^6}$ for some compact 6 dimensional manifold.
- That the theory should produce physics at the observable scales severely limits our choices of the compact manifold.
- **Requiring that supersymmetry is preserved at the compactification scale restricts us to the special class of Calabi-Yau Manifolds.**

Calabi-Yau Three-folds

Manifolds with 3 complex dimensions that are:

- Compact
- Kähler
  - Metric locally expressible as the derivative of a real scalar function $g_{a\bar{b}} = \partial_a \partial_{\bar{b}} \Phi(z^a, \bar{z}^{\bar{a}})$. Φ is called the Kähler potential
- Vanishing first Chern Class $\equiv$ SU(3) Holonomy $\equiv$ Has a nowhere vanishing Holomorphic 3-form



An Exciting Property of CY Compactifications

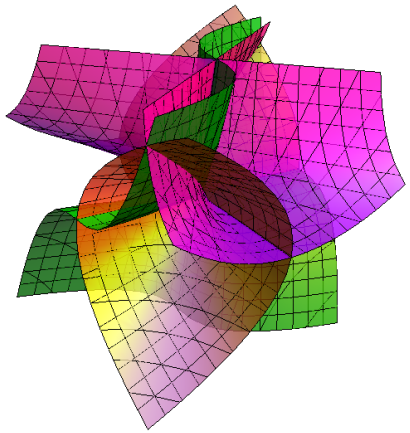
- Advance prediction of the number of chiral generations of particles ($\mathcal{N}$) present in the 4D theory from quite general considerations.
- For an effective field theory emerging from the Heterotic String (a supergravity multiplet and an E_8 x E_8 Yang-Mills Supermultiplet):

$$2\mathcal{N} = \chi(M)$$

$\chi(M)$: Euler characteristic of the Calabi-Yau space M.

$\mathcal{N}$: Number of chiral generations in the 4D theory

Complete Intersection Calabi-Yau Manifolds (CICYs)[1]



- Special class of Calabi-Yau manifolds embedded in products of complex projective spaces

$$M \subset \mathcal{CP}^1 \times \subset \mathcal{CP}^2 \times \subset \mathcal{CP}^1 \times \ldots$$

- Stringent restrictions on degrees of defining polynomial equations coming from the constraint of vanishing 1st Chern Class.

[1] Discovered by P.Candelas, A.Dale, C.Lutken and R.Schimmrigk, Nucl.Phys. B298 (1988) 493

CICY Models

- 7890+ models of String Compactifications.
- Models with $\chi(M) = -6$ and multiples of it exist in this list, which is very encouraging for phenomenology.
- Models with $\chi(M)$ as multiples of 6 can be quotient-ed by a free group action to yield a quotient manifold with $\chi(M) = -6$. Hence classification of free group actions on such CYs are important.

Origin of Discrete Symmetries in SSM

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Nuclear Physics B

Volume 368, Issue 1, 6 January 1992, Pages 3–37

Discrete gauge symmetries and the origin of baryon and lepton number conservation in supersymmetric versions of the standard model

Luis E. Ibáñez

CERN, 1211 Geneva 23, Switzerland

Graham G. Ross

Department of Theoretical Physics, Oxford OX1 3NP, UK

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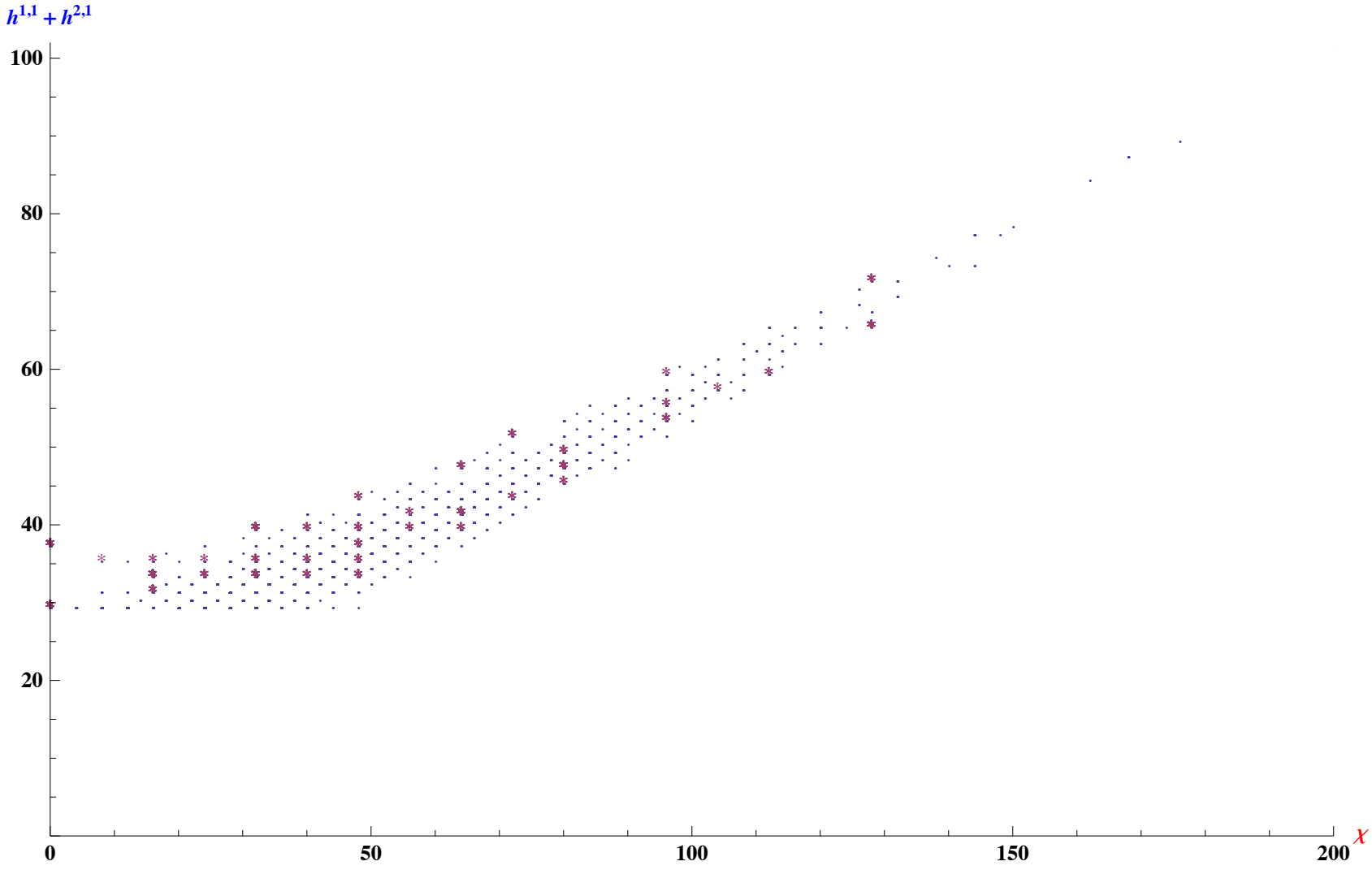
Stringy Origins of Discrete Symmetries

- In the Supersymmetric SM, certain discrete symmetries are assumed, to prohibit unacceptable violations of Baryon and Lepton number.
- Ordinary discrete symmetries can be violated by quantum gravity effects and cannot prohibit such violations or such unacceptable phenomenon as nucleon decay.
- 'Discrete Gauge Symmetries' are remnants of broken gauge symmetries and are good candidates for prohibiting such violations.
- We look for them in the Complex Calabi-Yau three folds!

Results on New Symmetry Searches

- Have established a mathematical bound for the order of toric symmetries acting non-freely on the CICYs.
- Have discovered new toric discrete symmetries of the CICYs.

New $\mathbb{Z}_2$ Symmetry Candidates



Physics Goals!

- To check if the new discrete toric symmetries are R-symmetries.
- Establish a gauge symmetry of which these new symmetries are remnants. This could serve as a mechanism for understanding the origin of discrete R-symmetries.
- Calculate discrete anomaly cancellation conditions from such a symmetry akin to the one by Ibanez and Ross.[2]

[2] Discrete gauge symmetry anomalies, Ibanez, Ross, Phys. Lett., B 260:291–295, 1991

Goals from Yesterday!

Bayern Munich 4 - 0 Barcelona

... meanwhile in the UK