F-theory models and their predictions for new physics phenomena

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$I\omega\alpha\nu\nu\iota\nu\alpha$

GREECE

Outline of the Talk

- ▲ $\mathcal{F}-$Theory: A few basic notions...
- ▲ Model building with F-theory
- ▲ $SU(5)$ and E_6 GUTs with exotic matter ...
- ▲ New Physics Implications (*The 750 GeV resonance*)
- ▲ Concluding Remarks

$\mathcal{A}$

F-Theory

why ?

★ **Advantages**

Consistent framework for unification

Calculability

testable predictions

Basic features of F-theory:

- ⋆ Geometrization of Type II-B String Theory
- ⋆ Elliptically fibred 8-dimensional compact space
- ⋆ Fibration described by a simple well known model (*Weierstrass model*)

... a short geometric description of fibration ...

Any cubic equation with a rational point can be written in:

★ Weierstrass form:

$$y^2 = x^3 + fx + g$$

▲ Two important quantities characterising elliptic curves:

1. The Discriminant:

$$\Delta = 4f^3 + 27g^2$$

... classifies the curves with respect to its singularities

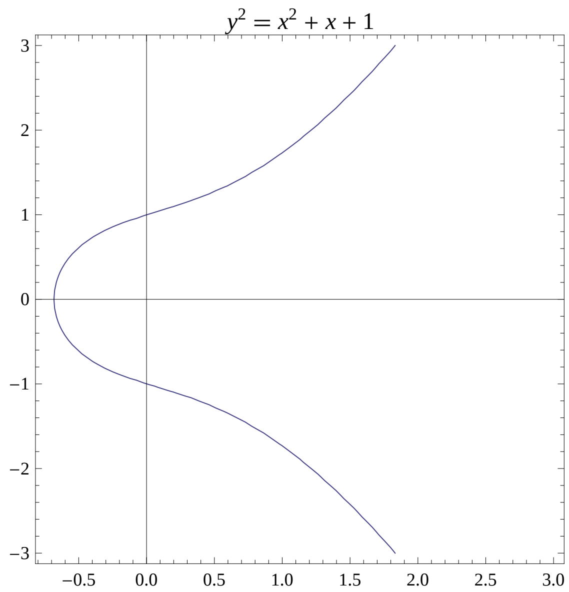
2. The j-invariant function:

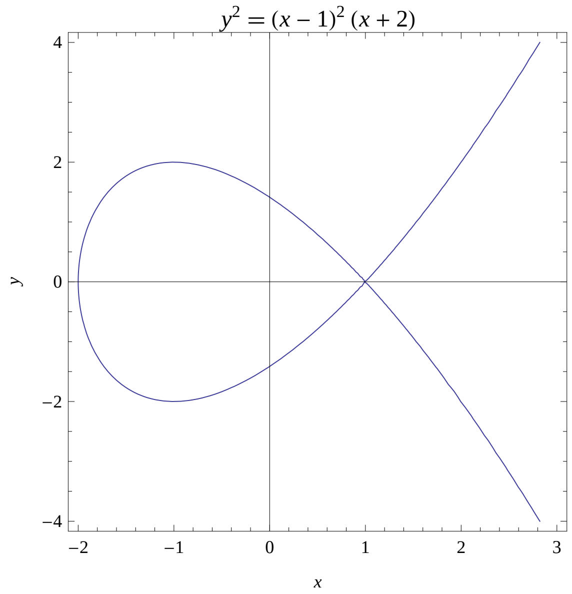
$$j = 4\,\frac{(24f)^3}{4f^3 + 27g^2}$$

... takes the same value for equivalent elliptic curves

basic ingredients: the elliptic curve equ and its discriminant:

$$y^2 = x^3 + fx + g, \quad \Delta = 4f^3 + 27g^2$$

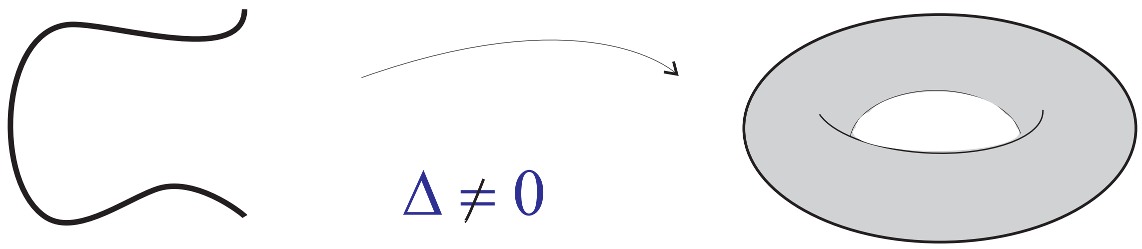




non-singular $\Delta \neq 0 \longleftarrow$ Elliptic Curves $\longrightarrow$ *singular* $\Delta = 0$

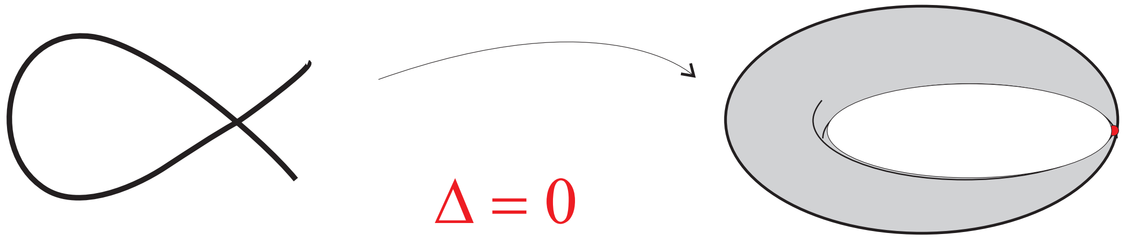
$y^2 = x^3 + f\,x + g$

Real **Complex**



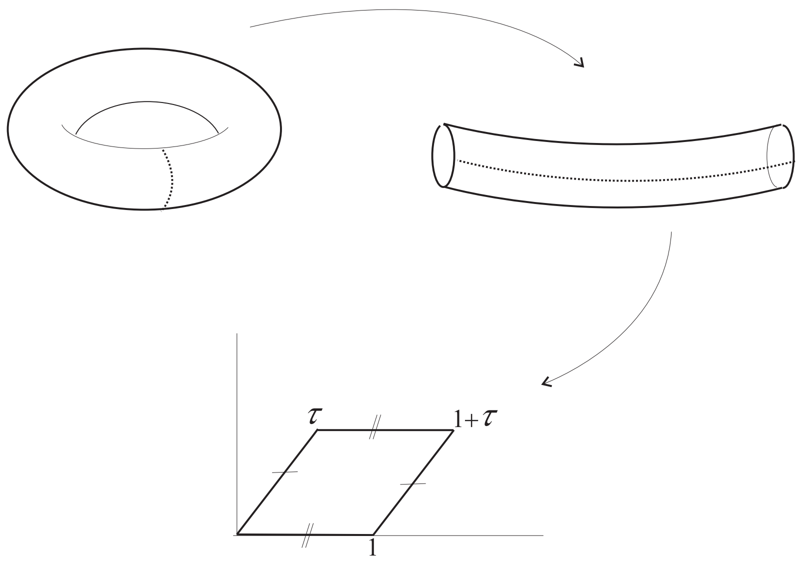
$\Delta \neq 0$

non-singular elliptic curve



$\Delta = 0$

singular elliptic curve



A torus cut along the two circles is topologically equivalent to a parallelogram.

Described by Complex Modulus: $\tau = \alpha + \beta\, i$.

★ F-theory ★

(*Vafa 1996*)

$\Downarrow$

Geometrisation of Type II-B superstring

II-B: *closed string spectrum obtained by combining left and right moving open strings with NS and R-boundary conditions:*

$$(NS_+, NS_+),\ (R_-, R_-),\ (NS_+, R_-),\ (R_-, NS_+)$$

Bosonic spectrum:

(NS_+, NS_+): graviton, dilaton and 2-form Kalb-Ramond-field:

$$g_{\mu\nu},\ \phi,\ B_{\mu\nu} \to B_2$$

(R_-, R_-): scalar, 2- and 4-index fields (p*-form potentials*)

$$\mathbf{C_0}, C_{\mu\nu}, C_{\kappa\lambda\mu\nu} \to C_p,\ p = 0, 2, 4$$

Definitions (F-*theory bosonic part*)

1. *String coupling:* $g_s = e^{-\phi}$

2. *Combining the two scalars* $C_0,\ \phi$ *to one modulus:*

$$\tau = C_0 + i\, e^{\phi} \rightarrow C_0 + \frac{i}{g_s}$$

(*recall that* τ *can describe a torus*)

$$\Downarrow$$

1. *Theory can be described by consistent properly invariant action*

2. ... gives the correct EoM

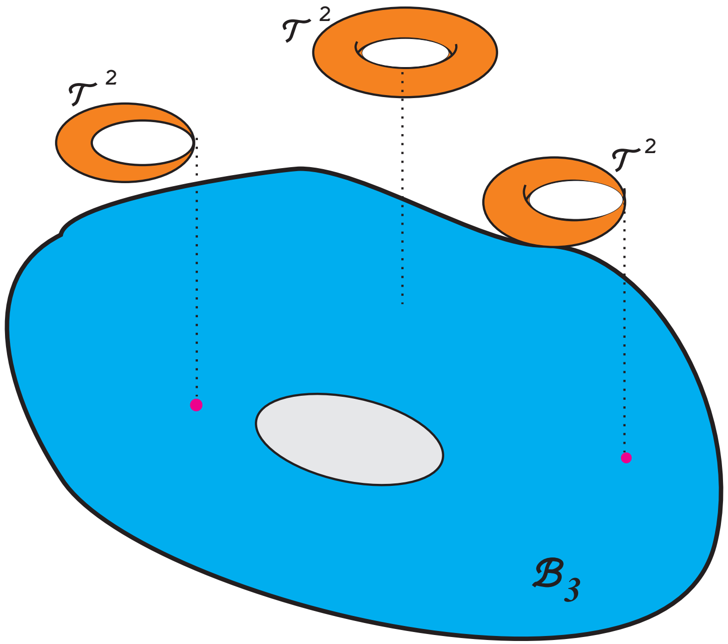
3. *Consistent with* $N = 1$ Supersymmetry

FIBRATION

▲ $\Rrightarrow$ 6-d compact space described by 3-complex dim. manifold $\mathcal{B}_3$

▲ $\Rrightarrow$ At each point on $\mathcal{B}_3$ assign a torus with modulus:

$$\tau = C_0 + \imath/g_s$$



$\Rrightarrow$ F-theory defined on $\mathcal{R}^{3,1} \times \mathcal{X}$

$\mathcal{X}$, *is called elliptically* fibered **CY** 4-fold over B_3

Elliptic Fibration

described by $\mathcal{W}$eierstraß $\mathcal{E}$quation

$$y^2 \quad = \quad x^3 + f(w)\, x z^4 + g(w) z^6$$

For each point of B_3, the above equation describes a torus

1. x, y, z homogeneous coordinates
2. $f(w),\ g(w) \to$ 8th and 12th degree polynomials.
3. Discriminant

$$\Delta(w) = 4\, f^3 + 27\, g^2$$

Fiber **singularities** at zeros of *Discriminant*:

$$\Delta(w) = 0 \to 24 \text{ roots } w_i$$

$$\Downarrow$$

Kodaira classification:

- Type of Manifold **singularity** is specified by the **vanishing order** of $f(w),\ g(w)$ and $\Delta(w)$
- **Geometric Singularities** classified in terms of $\mathcal{A}\,\mathcal{D}\,\mathcal{E}$ Lie groups (**Kodaira**$\sim$ 1960...).

Interpretation of geometric singularities

$$\Downarrow$$

$$\boxed{CY_4\text{-}\textbf{Singularities} \rightleftarrows \textbf{gauge symmetries}}$$

$$\textbf{Groups} \quad \to \quad \begin{cases} SU(n) \\ SO(m) \\ \mathcal{E}_n \end{cases}$$

Example:

$$f = w^3(b_3 + b_4 w + \cdots),\ g = w^4(c_4 + c_5 w + \cdots),\ \Delta = w^8(d_8 + d_9 w + \cdots) \to \mathcal{E}_6$$

ord(f)	ord(g)	ord(Δ)	fiber type	Singularity
0	0	n	I_n	A_{n-1}
≥ 1	1	2	II	none
1	≥ 2	3	III	A_1
≥ 2	2	4	IV	A_2
2	≥ 3	$n+6$	I_n^*	D_{n+4}
≥ 2	3	$n+6$	I_n^*	D_{n+4}
≥ 3	4	8	IV^*	E_6
3	≥ 5	9	III^*	E_7
≥ 4	5	10	II^*	E_8

Table 1: Vanishing order of the polynomials f, g and the discriminant Δ.

(The Kodaira classification)

Tate's Algorithm

$$y^2 + \alpha_1 x\, y\, z + \alpha_3 y\, z^3 = x^3 + \alpha_2\, x^2 z^2 + \alpha_4 x\, z^4 + \alpha_6 z^6$$

Table: *Classification of Elliptic Singularities w.r.t. vanishing order of Tate's form coefficients* α_i*:*

Group	α_1	α_2	α_3	α_4	α_6	Δ
$SU(2n)$	0	1	n	n	$2n$	$2n$
$SU(2n+1)$	0	1	n	$n+1$	$2n+1$	$2n+1$
$SU(5)$	0	1	2	3	5	5
$SO(10)$	1	1	2	3	5	7
$\mathcal{E}_6$	1	2	3	3	5	8
$\mathcal{E}_7$	1	2	3	3	5	9
$\mathcal{E}_8$	1	2	3	4	5	10

Basic ingredient in F-theory:

$D7$ - brane

GUTs are associated with 7-branes wrapping certain classes of *'internal'* **2-complex dim.** surface $\mathbf{S} \subset B_3$

▲ Gauge symmetry:

$$\mathcal{E}_8 \to \mathbf{G_{GUT}} \times \mathcal{C}$$

▲ $G_{GUT} = SU(5),\ SO(10),\ \ldots$

★ $\mathcal{C}$ *Group can be reduced by...* $\rightrightarrows$ *monodromies to:*

$$U(1)^n, \text{or some discrete symmetry}$$

... these act as family or discrete symmetries

$\mathcal{B}$

Models

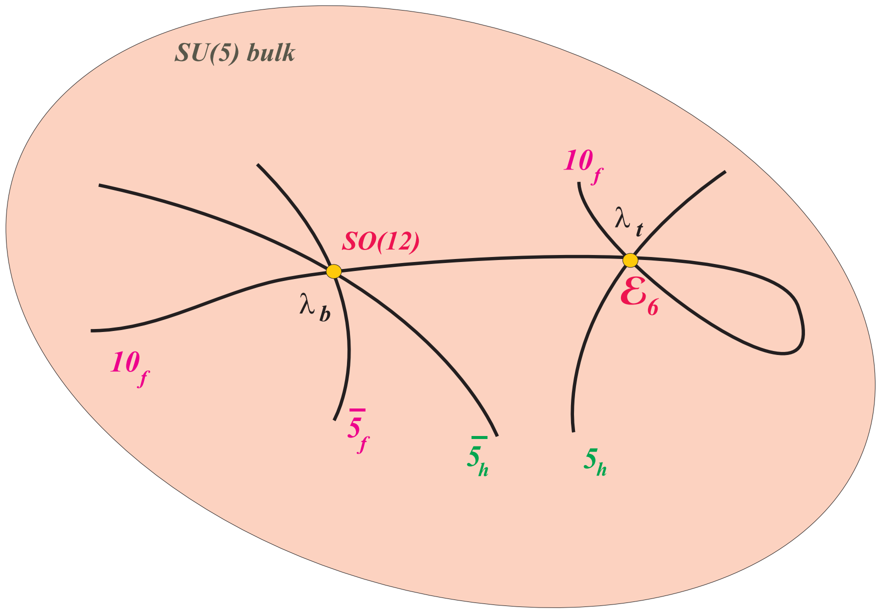
An $SU(5)$ Model

$$\mathcal{E}_8 \to SU(5) \times SU(5)_\perp \to \mathcal{C} = SU(5)_\perp.$$

Spectral Cover description: $SU(5)_\perp \longrightarrow$ described by Cartan roots:

$$t_i \;=\; SU(5) - \mathrm{roots} \to \sum_i t_i = 0$$

Matter resides in 10 and $\bar{5}$ along intersections with other 7-branes



$\lambda_{t,b}$-Yukawas at intersections and gauge symmetry enhancements

Fluxes:

$SU(5)$ Chirality

$SU(5)$ Symmetry Breaking

Splitting of $SU(5)$-reps

Two types of fluxes:

M_{10}, M_5:

associated with flux-restrictions on $U(1)$'s$\in$ $SU(5)_\perp$:

determine the chirality of complete $10, 5 \in SU(5)$.

N_Y:

related to Cartan generators of $SU(5)_{GUT}$.

They are taken along $U(1)_Y \in SU(5)_{GUT}$ and **split** $SU(5)$-reps.

$U(1)_\perp-$Flux on SM reps $\in \mathbf{10}$'s:

$$\#10 - \#\overline{10} = \begin{cases} n_{(3,2)_{\frac{1}{6}}} - n_{(\bar{3},2)_{-\frac{1}{6}}} & = & M_{10} \\ n_{(\bar{3},1)_{-\frac{2}{3}}} - n_{(3,1)_{\frac{2}{3}}} & = & M_{10} \\ n_{(1,1)_1} - n_{(1,1)_{-1}} & = & M_{10} \end{cases}$$

$U(1)_\perp-$ Flux on SM reps $\in \mathbf{5}$'s:

$$\#5 - \#\overline{5} = \begin{cases} n_{(3,1)_{-\frac{1}{3}}} - n_{(\bar{3},1)_{\frac{1}{3}}} & = & M_5 \\ n_{(1,2)_{\frac{1}{2}}} - n_{(1,2)_{-\frac{1}{2}}} & = & M_5 \end{cases}$$

(*...subject to:* $\sum_i M_{10}^i + \sum_j M_5^j = 0$)

$U(1)_Y-$**Flux**-splitting of $\mathbf{10}$'s:

$$
\begin{aligned}
n_{(3,2)_{\frac{1}{6}}} - n_{(\bar{3},2)_{-\frac{1}{6}}} &= M_{10} \\
n_{(\bar{3},1)_{-\frac{2}{3}}} - n_{(3,1)_{\frac{2}{3}}} &= M_{10} - N_{Y_{10}} \\
n_{(1,1)_1} - n_{(1,1)_{-1}} &= M_{10} + N_{Y_{10}}
\end{aligned}
$$

$U(1)_Y-$ **Flux**-splitting of $\mathbf{5}$'s:

$$
\begin{aligned}
n_{(3,1)_{-\frac{1}{3}}} - n_{(\bar{3},1)_{\frac{1}{3}}} &= M_5 \\
n_{(1,2)_{\frac{1}{2}}} - n_{(1,2)_{-\frac{1}{2}}} &= M_5 + N_{Y_5}
\end{aligned}
$$

(... *subject to* $\sum_i N^i_{Y_{10}} = \sum_j N^j_{Y_5} = 0, \ldots$ *etc*)

Fermion Mass Textures

Two ways to obtain Fermion Mass Hierarchy in F-theory

- All families on the same curve(s) ($\Sigma_{10}, \Sigma_{\bar{5}}$)

  Flux corrections $\Rightarrow$ Hierarchy...

- Families assigned on different matter curves ($\Sigma_{10}^{1,2,3}, \Sigma_{\bar{5}}^{1,2,3}$)

  Monodromy $\longrightarrow$ Rank one mass matrices at tree level.

  Hierarchy organised by $U(1)$**'s** from underlying E_8 via:

  Singlet vevs $\langle\theta_{ij}\rangle$

Choice: $\langle\theta_{14}\rangle \cdot \langle\theta_{43}\rangle \neq 0$

Rank one Quark mass matrices (*GKL and GG Ross*)

$$M_d = \begin{pmatrix} \lambda^d_{11}\theta^2_{14}\theta^2_{43} & \lambda^d_{12}\theta_{14}\theta^2_{43} & \lambda^d_{13}\theta_{14}\theta_{43} \\ \lambda^d_{21}\theta^2_{14}\theta_{43} & \lambda^d_{22}\theta_{14}\theta_{43} & \lambda^d_{23}\theta_{14} \\ \lambda^d_{31}\theta_{14}\theta_{43} & \lambda^d_{32}\theta_{43} & 1 \times \lambda^d_{33} \end{pmatrix} v_b, \tag{1}$$

$$M^u = \begin{pmatrix} \lambda^u_{11}\theta^2_{14}\theta^2_{43} & \lambda^u_{12}\theta^2_{14}\theta_{43} & \lambda^u_{13}\theta_{14}\theta_{43} \\ \lambda^u_{21}\theta^2_{14}\theta_{43} & \lambda^u_{22}\theta^2_{14} & \lambda^u_{23}\theta_{14} \\ \lambda^u_{31}\theta_{14}\theta_{43} & \lambda^u_{32}\theta_{14} & 1 \times \lambda^u_{33} \end{pmatrix} v_u \tag{2}$$

λ_{ij} computed from overlapping integrals ... *expected of* $\mathcal{O}(1)$.

Particles' Wavefunctions: solving EoM $\longrightarrow$ Gaussian profile: $\psi \sim f(z_i)e^{-M|z_i|^2}$

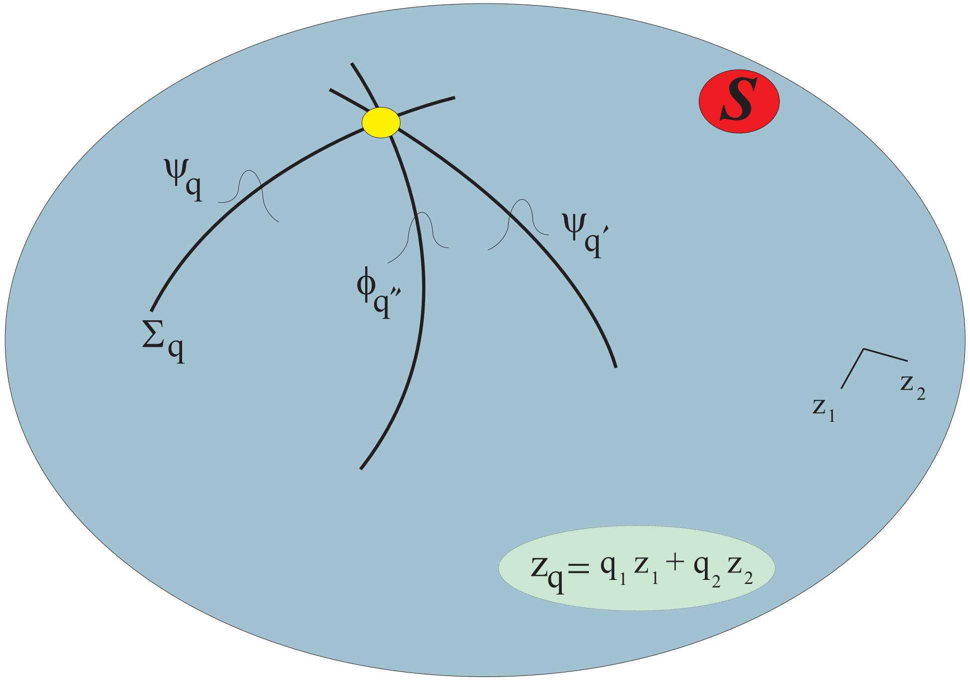


Figure 1: Overlapping of three wavefunctions at triple intersection (Yukawa coupling)

Strength of Yukawa coupling $\propto$ integral of overlapping ψ's at 3-intersection:

$$\lambda_{ij} \propto \int \psi_i(z_1, z_2)\psi_j(z_1, z_2)\psi_H(z_1, z_2)dz_1 \wedge dz_2 \approx 0.3 - 0.5$$

An $\mathcal{E}_6$ example

.

Karozas, King, GKL, Medowcroft, *arXiv:1601.00640*

Exotics unavoidable if gauge group $SO(10)$ or higher rank

★ Massless spectrum under $\mathcal{E}_6 \supset \Gamma_S \times H_S$ breaking :

$$\mathrm{ad}(\mathcal{E}_6) = \bigoplus \tau_j \otimes T_j$$

★ multiplicity of 4-d spectrum counted by topological invariant (Euler characteristic)

$$-n_j = \chi(S, \mathcal{L}_j) = 1 + \frac{1}{2} c_1(\mathcal{L}_j) \cdot c_1(\mathcal{L}_j) + \frac{1}{2} c_1(\mathcal{L}_j) \cdot c_1(S)$$

$$-n_j^* = \chi(S, \mathcal{L}^*) = 1 + \frac{1}{2} c_1(\mathcal{L}_j^*) \cdot c_1(\mathcal{L}_j^*) + \frac{1}{2} c_1(\mathcal{L}_j^*) \cdot c_1(S)$$

▲ $c_1(S), c_1(L)$ Chern classes (topological invariants counting independent sections)

Chiral states :

$$\chi(S, \mathcal{L}^*) - \chi(S, \mathcal{L}) = -c_1(\mathcal{L}) \cdot c_1(S)$$

Assuming

$$\mathcal{E}_6 \supset SU(3) \times SU(2) \times U(1)_{x'} \times U(1)_x \times U(1)_y$$

Line Bundles: (*suitable 'basis' for* (x', x, y)*-charges*)

$$\mathcal{L}_1 = (5,0,0), \ \ \mathcal{L}_2 = (1,4,0), \ \ \mathcal{L}_3 = (1,-1,-3) \tag{3}$$

Exotic	Multiplicity n_i	Exotic	Multiplicity n_i
$R = (\overline{3},2)_{\frac{5}{6}}$	$n_1 = -\chi(\mathcal{L}_1, S)$	$\bar{D} = (\overline{3},1)_{\frac{1}{3}}$	$n_6 = -\chi(\mathcal{L}_2 \otimes \mathcal{L}_3, S)$
$Q = (3,2)_{\frac{1}{6}}$	$n_2 = -\chi(\mathcal{L}_2, S)$	$L = (1,2)_{-\frac{1}{2}}$	$n_7 = -\chi(\mathcal{L}_1^{-1} \otimes \mathcal{L}_2 \otimes \mathcal{L}_3, S)$
$U = (3,1)_{\frac{2}{3}}$	$n_3 = -\chi(\mathcal{L}_1^{-1} \otimes \mathcal{L}_2, S)$	$E^{c'} = (1,1)_1$	$n_8 = -\chi(\mathcal{L}_1 \otimes \mathcal{L}_3, S)$
$E^c = (1,1)_1$	$n_4 = -\chi(\mathcal{L}_1 \otimes \mathcal{L}_2, S)$	$Q' = (3,2)_{\frac{1}{6}}$	$n_9 = -\chi(\mathcal{L}_3, S)$
$S' = (1,1)_0$	$n_5 = -\chi(\mathcal{L}_2^{-1} \otimes \mathcal{L}_3, S)$	$U^c = (\overline{3},1)_{-\frac{2}{3}}$	$n_{10} = -\chi(\mathcal{L}_1^{-1} \otimes \mathcal{L}_3, S)$

Table 2: Possible massless E_6 bulk exotics and their multiplicities

Conditions on the eliminatation of $R + \bar{R}$ exotics (*avoid lowering the unification scale*)

$$c_1(S) \cdot c_1(L_Y) = 0, \ c_1(L_Y) \cdot c_1(L_Y) = -2$$

can gauge couplings attain unification?

F-UNIFICATION: (*a simple case*)

$$\frac{1}{a_3(M_G)} = \frac{1}{a_G(M_G)}$$

$$\frac{1}{a_2(M_G)} = \frac{1}{a_G(M_G)} + x$$

$$\frac{1}{a_1(M_G)} = \frac{1}{a_G(M_G)} + \frac{3}{5}x$$

flux parameter $x = \frac{1}{2}\tau \int c_1(\mathcal{L}_Y)^2$.

(*Blumenhagen, Phys.Rev.Lett. 102 (2009) 071601 arXiv:0812.0248*)

RGE's

Consider n triplet fields $D, \bar{D}$ above M_X:

$$\frac{1}{a_i(M_Z)} = \frac{1}{a_i(M_G)} + \frac{b_i^x}{2\pi} \log \frac{M_G}{M_X} + \frac{b_i}{2\pi} \log \frac{M_X}{M_Z}$$

Combining...

$$(5(b_1^x - b_1) - 2(b_3^x - b_3)) \log \frac{M_G}{M_X} = 0 \qquad (4)$$

Contribution to β*-functions*: $b_1^x - b_1 = \frac{1}{5}(2n), \; b_3^x - b_3 = \frac{1}{2}(2n)$

eq.**??** satisfied $\forall$ number of $D, \bar{D}$ pairs and scale M_X!!

$$M_X \text{ scale} \Leftrightarrow \text{flux parameter } x$$

Unification and $\mathcal{E}_6$ **bulk** modes

Flux thresholds on Gauge couplings :

$$\frac{1}{a_Y(M_G)} = \frac{1}{a_1(M_G)} + \frac{2}{3}\frac{1}{a_3(M_G)}$$

Bulk Exotics contribution to RGE's ... reduces down to:

$$\gamma = -c_1(\mathcal{L}_2)^2 - c_1(\mathcal{L}_3)^2$$

The GUT scale:

$$M_G = e^{\frac{2\pi}{\beta A}} \left(\frac{M_I}{M_Z}\right)^{1-r} M_Z$$

The parameter r is fixed:

$$r = \frac{\beta}{\beta^I} = \frac{3}{5}$$

$$M_G = \left(\frac{M_Z}{91\mathrm{GeV}}\right)^{\frac{3}{5}} \left(\frac{M_I}{2.1\times 10^{16}\mathrm{GeV}}\right)^{\frac{2}{5}} 2.1\times 10^{16}\mathrm{GeV}$$

Low Energy Effective Model

All matter emerges from E_8-adjoint under $E_8 \supset E_6 \times SU(3)$

$$248 \to (78,1) + (1,8) + (27,3) + (\overline{27},\bar{3})$$

Spectral cover approach

Labeling of E_6 irreps with t_i the $SU(3)$ weights (subject to $t_1 + t_2 + t_3 = 0$)

$$(1,8) \to \theta_{13}, \theta_{31}; \quad (27,3) \to 27_{t_1}, 27_{t_3}; \quad (\overline{27},\bar{3}) \to \overline{27}_{-t_1}, \overline{27}_{-t_3} \tag{5}$$

Symmetry Breaking and Chirality obtained from Fluxes at the same time!

E_6	$SU(5)$	TeV spectrum	$\sqrt{10}Q_N$
27_{t_1}	$\overline{5}$	$3(d^c+L)$	1
27_{t_1}	10	$3(Q+u^c+e^c)$	$\frac{1}{2}$
27_{t_1}	5	$(3D+2H_u)$	-1
27_{t_1}	$\overline{5}$	$(3\overline{D}+2H_d)+H_d$	$-\frac{3}{2}$
27_{t_1}	1	θ_{14}	$\frac{5}{2}$
27_{t_3}	5	H_u	$-\frac{1}{2}$
27_{t_3}	1	$2\,\theta_{34}$	$\frac{5}{2}$
78	$\overline{5}$	$2\,X_{H_d}+X_{d^c}$	$-\frac{3}{2}$
78	5	$2\overline{X}_{\overline{H}_d}+\overline{X}_{\overline{d^c}}$	$\frac{3}{2}$

Table 3: The low energy spectrum for the F-theory E_6SSM-like model with TeV scale bulk exotics

Superpotential generating the μ term and exotic masses

$$\mathcal{W} \sim \lambda\theta_{14}H_dH_u + \lambda_{\alpha\beta\gamma}\theta_{34}^{\alpha}H_d^{\beta}H_u^{\gamma} + \kappa_{\alpha jk}\theta_{34}^{\alpha}\overline{D}_jD_k \tag{6}$$

In general $F and D$-flantess of $\mathcal{W}$ drive $\langle\theta_{ij}\rangle$ at M_{GUT}.

$$\sum_{ij} Q^A \left(|\langle\theta_{ij}\rangle|^2 - |\langle\theta_{ji}\rangle|^2\right) = -\frac{\mathrm{Tr}Q^A}{192\pi^2}g_s^2M_S^2$$

However $\exists$ solution:

$$\langle\theta_{14}\rangle \leq 1\,\mathrm{TeV} \rightarrow \mu\text{-term}$$
$$\theta_{34} \rightarrow X \text{ soft mass} \sim 750 \text{ GeV}$$

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New Physics Implications

RUN-II LHC results with pp-collisions

Excess of diphoton events at invariant mass 750 GeV

ATLAS: $\sigma(pp \to \gamma\gamma) \sim 10$ fb, local significance 3.9σ. Broad Width 45 GeV

CMS: $\sigma(pp \to \gamma\gamma) \sim 6$ fb, local significance 3.4σ. Narrow Width

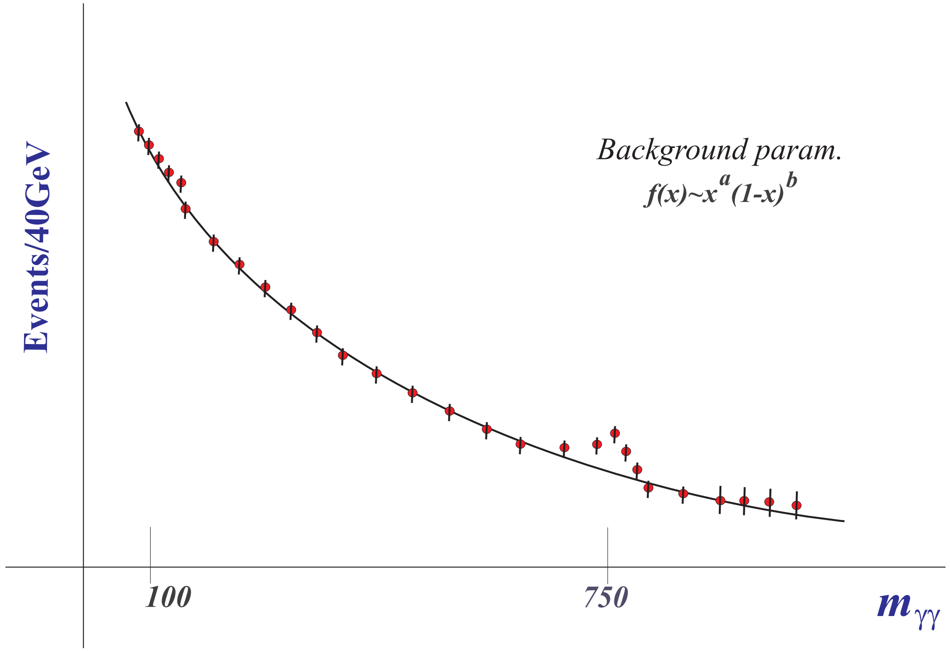


Figure 2: Solid curve: $f(x)$ background fit function with $x = \frac{m_{\gamma\gamma}}{\sqrt{s}}$ (qualitative depiction)

Vector-like pairs in $\mathcal{W}$*-terms give rise to the following diagram*

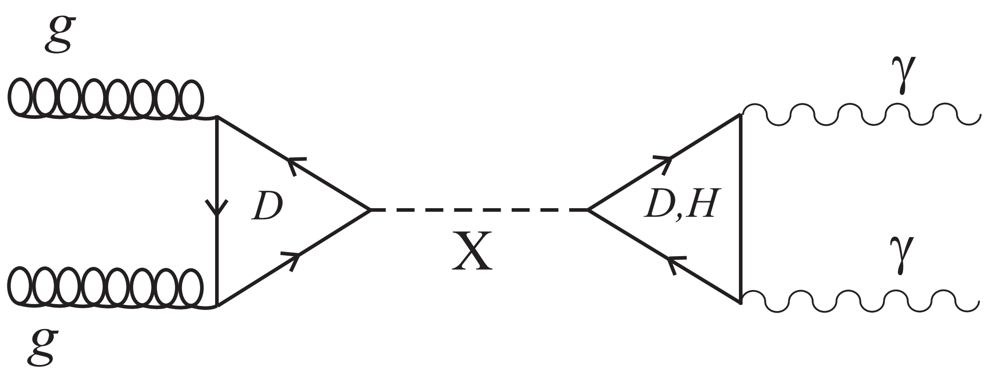


Figure 3: Production of X from gluon fusion and decay to $\gamma\gamma$

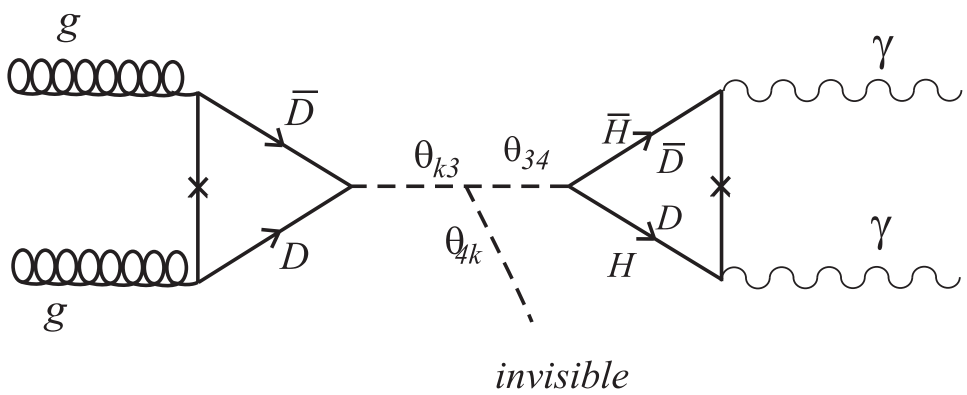


Figure 4: Decay to invisible particles

$$\mathcal{W} \supset \theta_{ij}\theta_{ik}\theta_{ki} \ .$$

Induced effective lagrangian

$$\mathcal{L}_{eff} \propto -\frac{1}{4} X \left(g_{X\gamma} F_{\mu\nu} F^{\mu\nu} + g_{Xg} G_{\mu\nu} G^{\mu\nu} \right)$$

Production: Gluon fusion $gg \to X$:

$$\sigma(pp \to X) = \frac{1}{M_X \cdot s} C_{gg} \Gamma(X \to gg)$$

$$C_{gg} = \frac{\pi^2}{8} \int_{M_X^2/s}^{1} \frac{dx}{x} g(x) g(M_X^2/sx)$$

Decay:

$$\mathrm{BR}(X \to \gamma\gamma) = \frac{\Gamma(X \to \gamma\gamma)}{\Gamma(X \to gg) + \Gamma(X \to \gamma\gamma)}$$

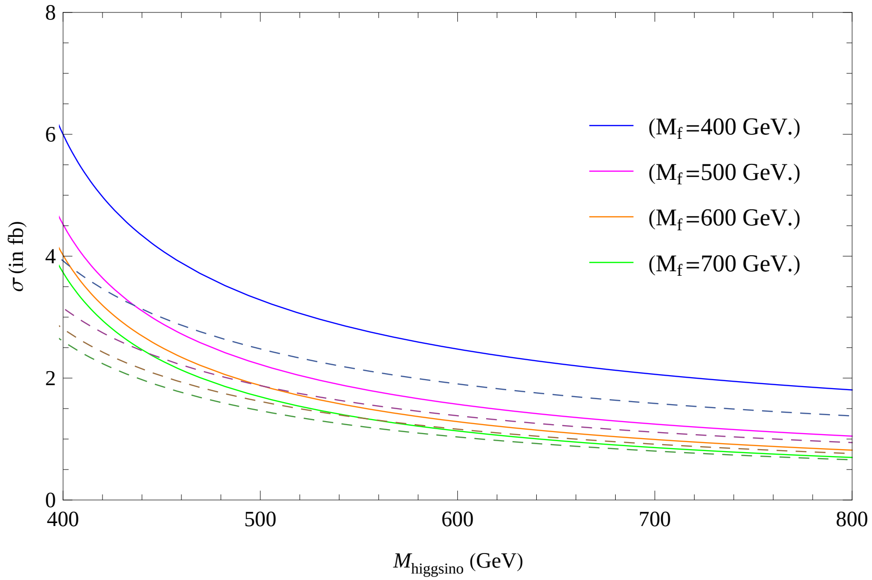
$\to$ *putative* signal consistent with $\rightsquigarrow$ $\boxed{\sigma \times \mathrm{BR} \approx 6 \pm 2 \mathrm{fb}}$

Cross Section:

$$\sigma(pp \to X \to \gamma\gamma) = \frac{1}{M_X \Gamma \cdot s} C_{gg} \Gamma(X \to gg) \Gamma(X \to \gamma\gamma)$$

$$\frac{\Gamma(X \to gg)}{M_X} \approx 7.2 \times 10^{-5} \left| \sum_i C_{r_i} y_i \frac{M_X}{2M_i} \right|^2 , \quad (7)$$

$$\frac{\Gamma(X \to \gamma\gamma)}{M_X} \approx 5.4 \times 10^{-8} \left| \sum_i d_{r_i} Q_i^2 y_i \frac{M_X}{2M_i} \right|^2 \quad (8)$$



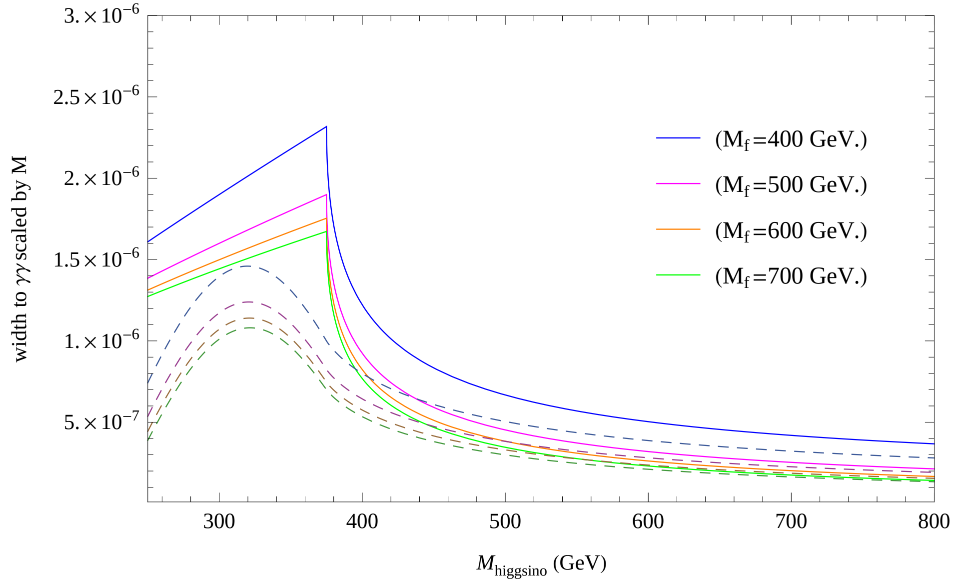


Figure 5: *left*: cross section as a function of the higgsino mass for various $M_{f\bar{f}}$ masses
left: $\Gamma_{\gamma\gamma}/M_X$ plot for the same parameter space.

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Concluding remarks

F-theory models :

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Geometric interpretation of GUTs

Calculability, form handful of topological properties, natural Doublet-Triplet splitting...

Prediction of Vector-like pairs and singlets ...

hints for New Physics

Capable of interpreting recent LHC data on diphoton events leading physics research to an exciting era !!!

does this point to the existence of String Theory? ...

not necessarily

but...

$\Downarrow\Downarrow\Downarrow$

String Theory .. shows us how a consistent theory should look like!