Building a social network of elliptic fibrations for F-theory

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Based on arXiv: 1401.5084, in collaboration with S.Krippendorf, P. Oehlmann and F. Rühle
and work in progress with D. Klevers, P. Oehlmann, H. Piragua and J. Reuter

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Plan

- Introduction and motivation
- $SU(5)$ models with extra $U(1)$s
- Toric non-Abelian factors
- The social network
- Conclusions and Prospects

Introduction and motivation

- Plenty of good reasons to use F-theory for model building.

See talks from Monday morning

- In F-theory compactifications, gauge DoF's, matter and interactions are tracked by the fiber degenerations at various base codimensions.

Kodaira'63, Bershadsky *et. al.*'96,...

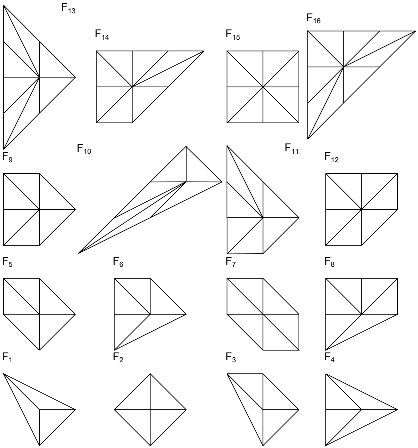
- Most model building efforts in the direction of GUTs.
- Phenomenology can be kept under control by virtue of additional $U(1)$ symmetries.

Beasley, Braun, Dolan, Dudas, Grimm, Hayashi, Heckman, Keitel, Marchesano, Marsano, Mayrhofer, Palti, Schäfer Nameki, Vafa, Watari, Weigand,. . .

- $U(1)$s from extra sections in the elliptic fibration.

Morrison, Vafa'96; Morrison, Park'12

Introduction and motivation



Kreuzer, Skarke'97

- Toric Mordell Weil (MW) group

  Braun, Grimm, Keitel'13

- Introduce an extra $SU(5)$ factor

  Borchman, Mayrhofer, Palti, Weigand'13
  Braun, Grimm, Keitel'13
  Cvetic, Klevers, Piragua'13

- Fibers with torsional MW

  Mayrhofer, Morrison, Till, Weigand'14

- Fibrations with multisections

  Anderson, García-Etxerbarria, Grimm, Keitel'14

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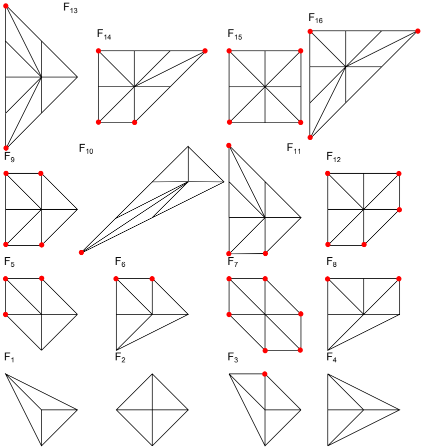

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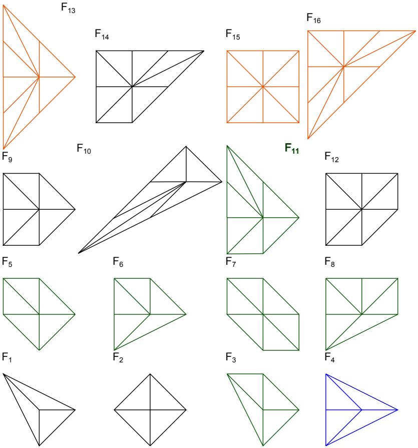

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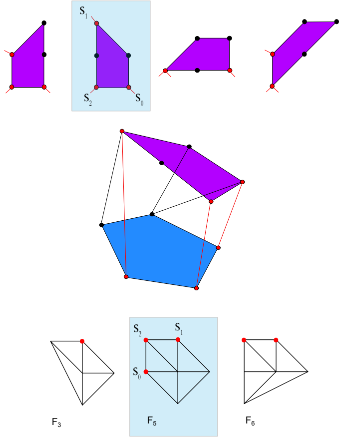
$SU(5)$ models with extra $U(1)$s



Borchman, Mayrhofer, Palti, Weigand'13

- $U(1)$ charges fixed by intersections of the sections with irreducible fiber components.
- For the $SU(5)$ top one has a single $\mathbf{10}$ curve and five $\mathbf{5}$ curves.
- Singlets

Curve	$\mathbf{1}_1$	$\mathbf{1}_2$	$\mathbf{1}_3$	$\mathbf{1}_4$	$\mathbf{1}_5$	$\mathbf{1}_6$
q_1	-5	5	5	-5	0	0
q_2	5	0	10	-5	-10	5

$SU(5)$ models with extra $U(1)$s

- Fluxes are needed in order to achieve a chiral spectrum.

see talks by M. Cvetic and S. Schäfer-Nameki

  - If outside $SU(5)$, it induces the net chirality.
  - If inside $SU(5)$ (hypercharge flux) it breaks to SM and projects out certain pieces of the $SU(5)$ representations.

$$\begin{array}{llll} \mathbf{10}_a : & (\mathbf{3},\mathbf{2})_{1/6} & : & M_a\,, \\ & (\overline{\mathbf{3}},\mathbf{1})_{-2/3} & : & M_a - N_a\,, \\ & (\mathbf{1},\mathbf{1})_{1} & : & M_a + N_a\,, \end{array} \qquad \begin{array}{llll} \overline{\mathbf{5}}_i : & (\overline{\mathbf{3}},\mathbf{1})_{1/3} & : & M_i\,, \\ & (\mathbf{1},\mathbf{2})_{-1/2} & : & M_i + N_i\,, \end{array}$$

Flux quanta subjected to anomaly cancelation.

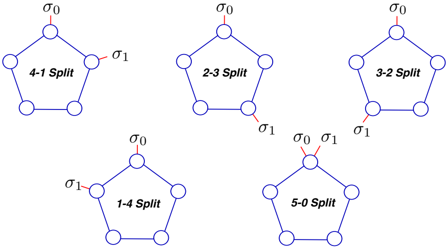
Dudas, Palti'10; Dolan, Marsano, Saulina, Schäfer-Nameki'11; Palti'12

$\Rightarrow$ No models of physical relevance which satisfy anomaly relations!

$SU(5)$ models with extra $U(1)$s

- *To take home:* The pattern of charges is more or less fixed by the splitting.

Braun, Grimm, Keitel'13



namely,

$$q_{\bar{\mathbf{5}}} = Q_{\bar{\mathbf{5}}} + 5\mathbb{Z}\,, \quad q_{\mathbf{10}} = Q_{\mathbf{10}} + 5\mathbb{Z}\,,$$

$$q_{\mathbf{1}} = 5\mathbb{Z}\,.$$

Split	5-0	4-1	3-2	2-3	1-4
$Q_{\bar{\mathbf{5}}}$	0	1	2	3	4
$Q_{\mathbf{10}}$	0	3	1	4	2

$SU(5)$ models with extra $U(1)$s

- A Benchmark Model

Curve	q_1	q_2	M	N	Matter
$\mathbf{10}$	-3	-1	3	0	$(Q+\bar{u}+\bar{e})_{1,2,3}$
$\bar{\mathbf{5}}_1$	9	-2	0	1	L_1
$\bar{\mathbf{5}}_2$	9	-7	1	-1	$\bar{d}_1$
$\bar{\mathbf{5}}_3$	-1	8	2	-1	$L_2+\bar{d}_{1,2}$
$\bar{\mathbf{5}}_4$	-1	-7	0	1	L_3
$\bar{\mathbf{5}}_5$	-6	8	0	1	H_d
$\bar{\mathbf{5}}_6$	-6	-2	0	-1	H_u

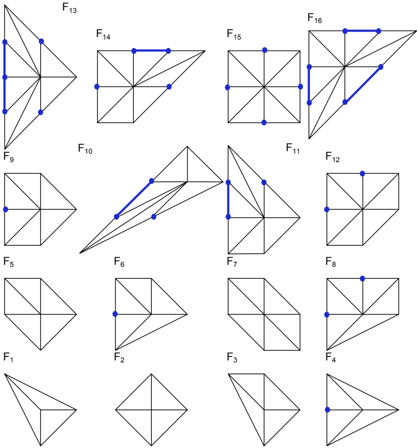
- Textures *à la* Froggatt-Nielsen
  - $q(s_1) = (5,0)$
  - $q(s_2) = (0,10)$

- Top Yukawa of order 1

see talks by F. Marchesano and G. Zoccarato

- μ-term could be generated in the Kähler potential.
- Dimension four proton decay operators forbidden.
  $\rightarrow$ Singlet config. leave a $\mathbb{Z}_2$ matter parity!

Toric non-Abelian factors



In the meantime...

- Embedding the fiber in a toric ambient space also gives us non-Abelian factors.
- We aim at finding the spectra in all of these cases (we focus on threefolds)
- Can we relate between models by means of Higgs mechanisms?

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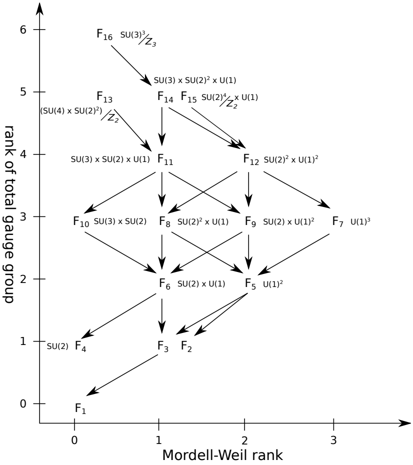
The social network



- All fibrations related by Higgs mechanisms in the field theory.
- Many attractive gauge group structures.
- Network is symmetric with respect to Gauge group rank=3.
- We can get them all from any of the three models torsional MW

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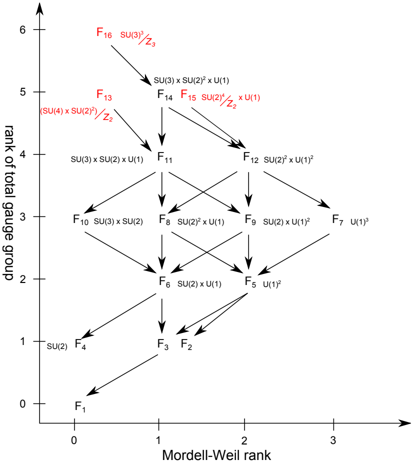

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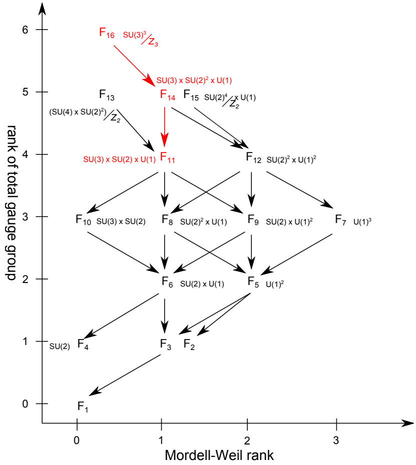

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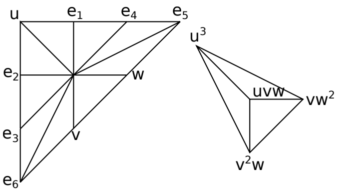
The social network

- F_{16}

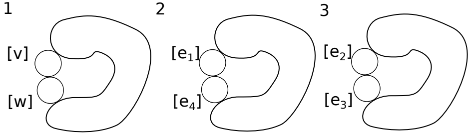


$$P_{16} = s_1 u^3 + s_6 uvw + s_7 v^2 w + s_9 vw^2 = 0\,,$$

- Discriminant

$$\Delta_{16} \sim s_1^3 s_7^3 s_9^3 (s_6^3 + 27 s_1 s_7 s_9)$$

- Gauge Symmetry



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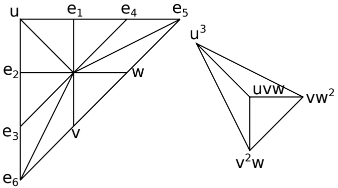

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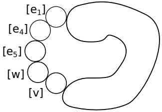
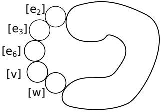
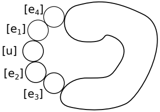
- Matter



$(\mathbf{3}, \bar{\mathbf{3}}, \mathbf{1})$



$(\mathbf{3}, \mathbf{1}, \bar{\mathbf{3}})$



$(\mathbf{1}, \mathbf{3}, \bar{\mathbf{3}})$

The social network

- $F_{16} \to F_{14}$
- VEV: $(\mathbf{3}, \mathbf{1}, \bar{\mathbf{3}})$

$$\langle \phi \rangle = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & v \end{pmatrix} .$$

This breaks $SU(3)^3/\mathbb{Z}_3 \to SU(3) \times SU(2)^2 \times U(1)$

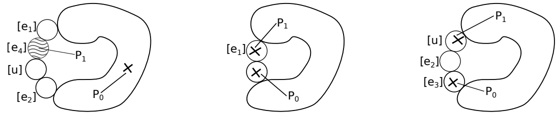
$$\begin{array}{ll}
(\mathbf{3},\bar{\mathbf{3}},\mathbf{1}) & \to (\mathbf{2},\bar{\mathbf{3}},\mathbf{1})_{-1/6} + (\mathbf{1},\bar{\mathbf{3}},\mathbf{1})_{1/3} \\
(\mathbf{3},\mathbf{1},\bar{\mathbf{3}}) & \to (\mathbf{2},\mathbf{1},\mathbf{2})_0 + (\mathbf{2},\mathbf{1},\mathbf{1})_{1/2} + (\mathbf{2},\mathbf{1},\mathbf{1})_{-1/2} + (\mathbf{1},\mathbf{1},\mathbf{1})_0 \\
(\mathbf{1},\mathbf{3},\bar{\mathbf{3}}) & \to (\mathbf{1},\mathbf{3},\mathbf{2})_{1/6} + (\mathbf{1},\mathbf{3},\mathbf{1})_{-1/3} \\
\hline
(\mathbf{8},\mathbf{1},\mathbf{1}) & \to (\mathbf{3},\mathbf{1},\mathbf{1})_0 + (\mathbf{2},\mathbf{1},\mathbf{1})_{1/2} + (\mathbf{2},\mathbf{1},\mathbf{1})_{-1/2} + (\mathbf{1},\mathbf{1},\mathbf{1})_0 \\
(\mathbf{1},\mathbf{8},\mathbf{1}) & \to (\mathbf{1},\mathbf{8},\mathbf{1})_0 \\
(\mathbf{1},\mathbf{1},\mathbf{8}) & \to (\mathbf{1},\mathbf{1},\mathbf{3})_0 + (\mathbf{1},\mathbf{1},\mathbf{2})_{1/2} + (\mathbf{1},\mathbf{1},\mathbf{2})_{-1/2} + (\mathbf{1},\mathbf{1},\mathbf{1})_0
\end{array}$$

Match the states and multiplicities in F_{14}.

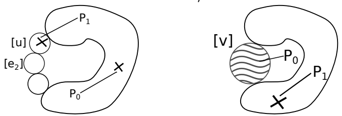
The social network

- $F_{14} \to F_{11}$
- VEV: $(\mathbf{1}, \mathbf{1}, \mathbf{2})_{1/2}$

  Breaking: $SU(3) \times SU(2)^2 \times U(1) \to SU(3) \times SU(2) \times U(1)$



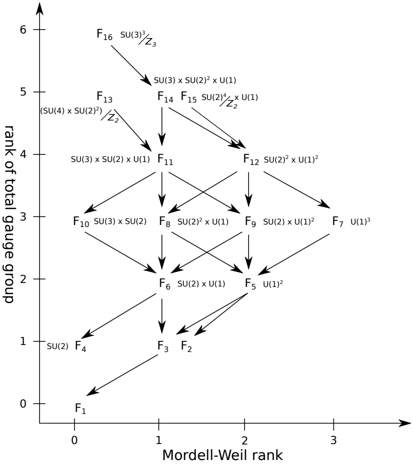
$(\mathbf{3}, \mathbf{2})_{-1/6}$ $(\mathbf{1}, \mathbf{2})_{1/2}$ $(\mathbf{3}, \mathbf{1})_{-2/3}$



$(\mathbf{3}, \mathbf{1})_{1/3}$ $(\mathbf{1}, \mathbf{1})_{-1}$

for SM realizations with tops see talk by T. Weigand and L. Lin

Conclusions and prospects



- We obtained (bottom-up) models with the exact MSSM spectrum (up to singlet extensions) with potential semi-realistic interactions.
- We need to go beyond available constructions (beyond $SU(5)$ GUTs?)
- Many appealing models left to be explored. There are intriguing relations among them.

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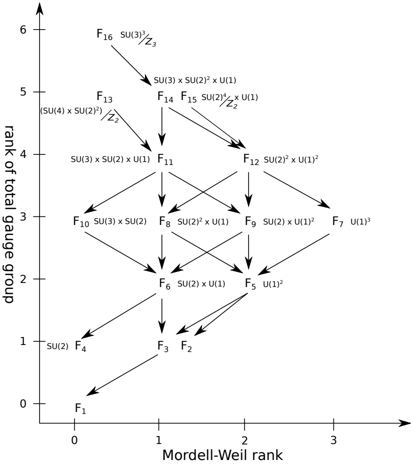

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Thanks!