# Yukawa couplings from F-Theory

Federico Carta

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Structure of the talk:

- Part 1. $SU(5)$ GUT in Type IIB.
- Part 2. F-Theory.
- Part 3. The $E_7$ model.

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\begin{aligned}
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&- y_d^{ij}\frac{\varphi_1}{\sqrt{2}}\bar{u}_L^i d_R^j - y_e^{ij}\frac{\varphi_2}{\sqrt{2}}\bar{e}_L^i e_R^j - y_u^{ij}\frac{\varphi_1}{\sqrt{2}}\bar{\nu}_L^i e_R^j + h.c.
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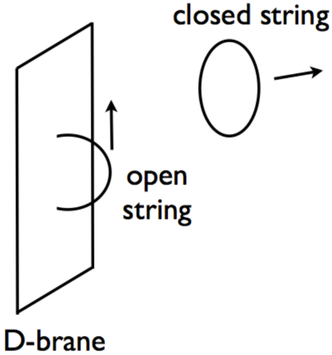

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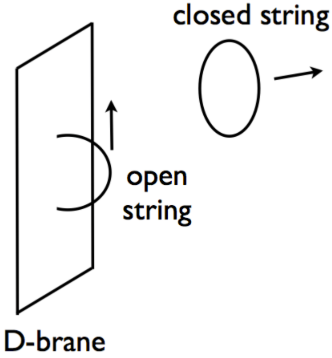


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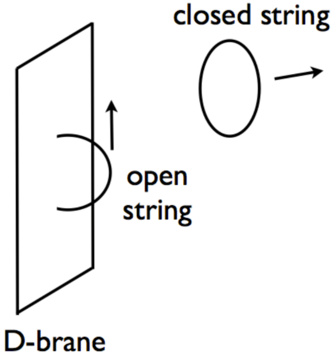


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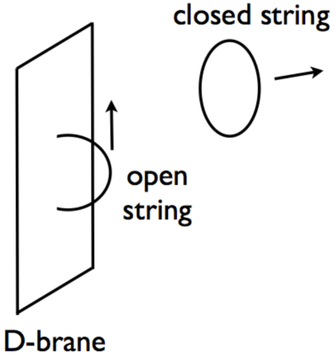


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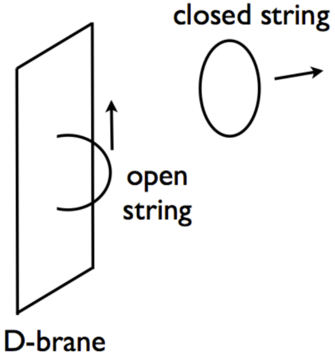


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Can't realize $10_M 10_M 5_U$ in perturbative Type IIB.

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- Treat $\tau$ as the complex structure of a torus.

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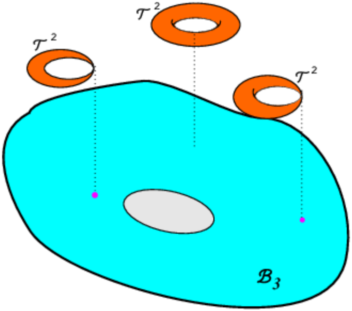

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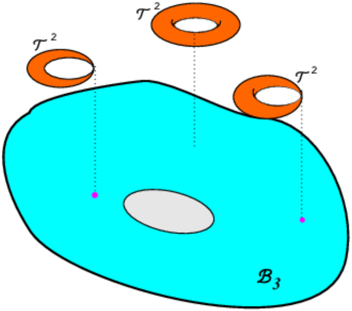


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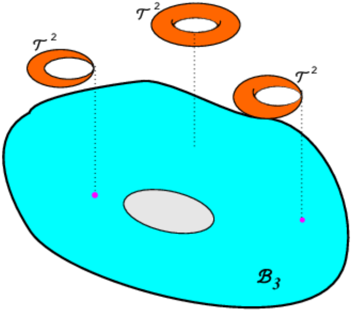


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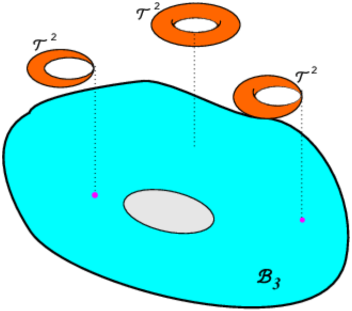


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- The 7-brane is wrapped there.

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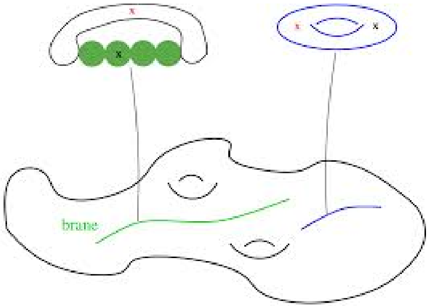

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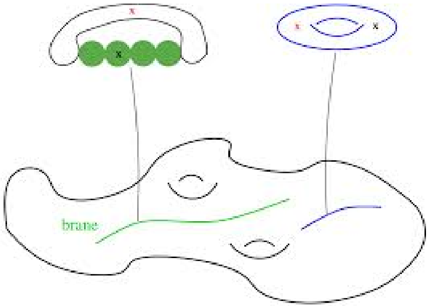


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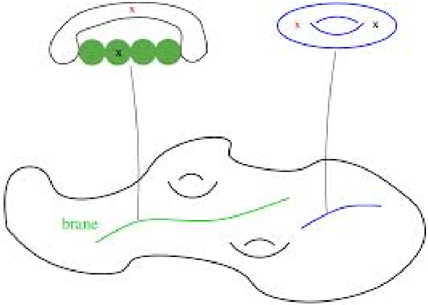


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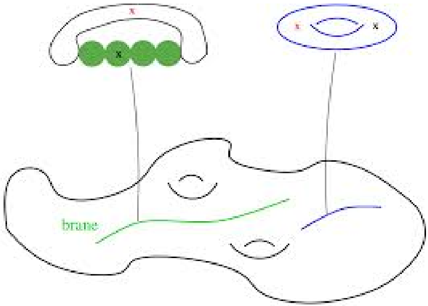


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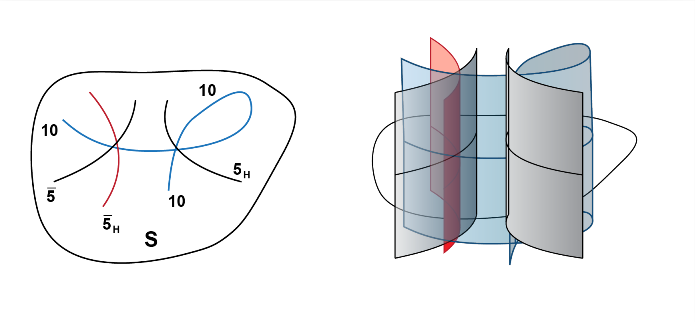
# The Matter curves for a $SU(5)$ GUT



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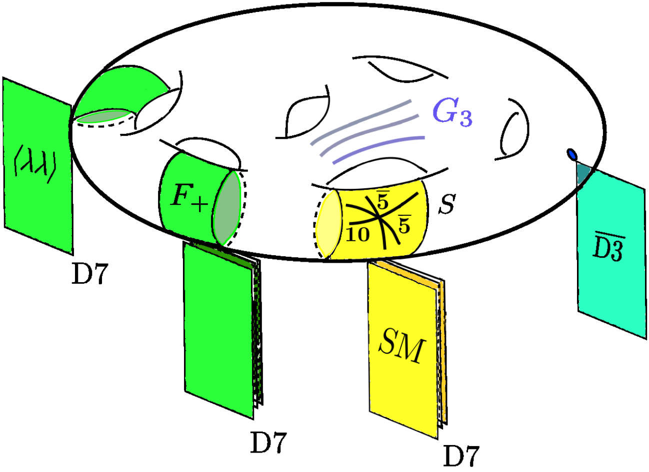
# All the ingredients together



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$$W = \int_S F^{(2,0)} \wedge \Phi = \int_S \bar{\partial} A \wedge \Phi + \boxed{\int_S A \wedge A \wedge \Phi}$$

[Beasly, Heckman, Vafa 2008]

- The Yukawa matrix has rank 1.

# The computation

- In one yukawa point, $G$ is enhanced to $E_6$. Mass for up.
- In the other yukawa point, $G$ is enhanced to $SO(12)$.
  Mass for down and leptons.
- Up+Down in just 1 Yukawa point. [Heckman, Tavanfar, Vafa, 2009]
- Find a group that contains both?
- $E8$ [Marchesano, Zoccarato, Regalado 2015] or $E_7$ [Marhcesano, Zoccarato, F.C, to appear]
- Dimensionally reduce the $8d$ SYM superpotential

$$W = \int_S F^{(2,0)} \wedge \Phi = \int_S \bar{\partial} A \wedge \Phi + \boxed{\int_S A \wedge A \wedge \Phi}$$

  [Beasly, Heckman, Vafa 2008]
- The Yukawa matrix has rank 1. Only the top is massive.

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- Hierarchical structure $\left(\mathcal{O}(1), \mathcal{O}(\epsilon), \mathcal{O}(\epsilon^2)\right)$ In our case:

$$Y_{D/L} = \begin{pmatrix} 0 & 0 & \epsilon Y^{13} \\ 0 & \epsilon Y^{22} & \epsilon Y^{23} \\ \epsilon Y^{31} & \epsilon Y^{32} & Y^{33} \end{pmatrix} + \mathcal{O}(\epsilon^2)$$

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Finally, compare with empirical data.

# Fermion masses at GUT scale

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Accomodate GUT scale MSSM masses for $\tan\beta$ $10-20$.

| $\tan\beta$ | 10 | 38 | 50 |
|---|---|---|---|
| $m_u/m_c$ | $2.7\pm0.6\times10^{-3}$ | $2.7\pm0.6\times10^{-3}$ | $2.7\pm0.6\times10^{-3}$ |
| $m_c/m_t$ | $2.5\pm0.2\times10^{-3}$ | $2.4\pm0.2\times10^{-3}$ | $2.3\pm0.2\times10^{-3}$ |
| $m_d/m_s$ | $5.1\pm0.7\times10^{-2}$ | $5.1\pm0.7\times10^{-2}$ | $5.1\pm0.7\times10^{-2}$ |
| $m_s/m_b$ | $1.9\pm0.2\times10^{-2}$ | $1.7\pm0.2\times10^{-2}$ | $1.6\pm0.2\times10^{-2}$ |
| $m_e/m_\mu$ | $4.8\pm0.2\times10^{-3}$ | $4.8\pm0.2\times10^{-3}$ | $4.8\pm0.2\times10^{-3}$ |
| $m_\mu/m_\tau$ | $5.9\pm0.2\times10^{-2}$ | $5.4\pm0.2\times10^{-2}$ | $5.0\pm0.2\times10^{-2}$ |
| $Y_\tau$ | $0.070\pm0.003$ | $0.32\pm0.02$ | $0.51\pm0.04$ |
| $Y_b$ | $0.051\pm0.002$ | $0.23\pm0.01$ | $0.37\pm0.02$ |
| $Y_t$ | $0.48\pm0.02$ | $0.49\pm0.02$ | $0.51\pm0.04$ |

[Ross Serna, 2007]

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- There is a unique consistent $E_7$ model that gives a good hierarchy.
- We generate correctly chirality and doublet-triplet splitting.
- $\tau - b$ non-unification is achieved.
- Separating the point a tiny bit generates a CKM.

*Thank you.*