From D-brane instantons to Bipartite Field Theories.

Eduardo García-Valdecasas Tenreiro

Instituto de Física Teórica UAM/CSIC, Madrid

Based on 1805.00011 by Sebastian Franco, E.G. & Angel Uranga

String Phenomenology 2018, University of Warsaw, 4th July 2018
Outline

1. Motivation and Introduction.
2. The recipe.
3. Applications.
Motivation and Introduction
Toric Field Theories are a nice playground for relationships between Field Theory and String Theory → Realized in String Theory as the World-Volume theory inside a D3-brane probing a toric CY singularity.

Their natural generalization are Bipartite Field Theories (BFTs), rarely realized in String Theory. (Franco, 2012; Heckman et al., 2013; Franco & Uranga, 2014)

D-brane instantons can be understood as a deformation in the geometry. (Koerber & Martucci, 2007; Koerber & Martucci, 2008; EGV & Uranga, 2017b; EGV & Uranga, 2017a)

This induces an operation in Toric Field Theories, easily translated to their associated Dimer models.

⇒ This operation can yield BFTs, thus realizing them in String Theory.
Dimers and BFT’s

- D3-branes probing a toric CY$_3$ singularity have inside them a gauge theory describable as a quiver diagram + superpotential. Or a dimer diagram, which is a tiling of $\mathbb{T}^2$. The mirror geometry is a CY$_3$ with a set of 3-cycles where D6-branes wrap. The relevant information are 1-cycles in a Riemann surface.

- Toric Field Theories generalize to BFTs, encoded in the tiling of a genus $g$ Riemann surface.
  $\Rightarrow$ For a $g = 2$ BFT, (d) above would be a tiling of an octagon.
The Recipe
Putting a D-brane instanton in a 3-cycle in the mirror geometry makes it vanish and cuts the $2k$ intersecting cycles, making the **D6-branes** on them **recombine**. Generically:

$$\Delta g = \frac{1}{2}(\Delta E - \Delta F - \Delta V) = k - 1$$

⇒ Generically **yields a BFT**!
A D-brane instanton sits in a gauge factor, a face in the dimer. The resulting theory is obtained by the following **recipe:**

1. Remove the face corresponding to the instanton.
2. Fuse the nodes colorwise, preserving ordering and introducing any necessary handles.
Applications
A couple of Examples

- An instanton on face 4 of $PdP_2$

$$W = \Phi_1 \Phi_2 \Phi_9 + \Phi_3 \Phi_4 \Phi_5 + \Phi_6 \Phi_7 \Phi_8 - $$
$$-\Phi_2 \Phi_3 \Phi_5 - \Phi_1 \Phi_6 \Phi_4 - \Phi_7 \Phi_9 \Phi_8$$

$$\text{genus} = 2$$

⇒ The obtained BFT's have the same quiver but different genus! The superpotential is different.

- An instanton on face 1 of $PdP_4$

$$W = \Phi_5 \Phi_4 \Phi_3 \Phi_8 \Phi_7 + \Phi_2 \Phi_1 \Phi_6 \Phi_9 - $$
$$-\Phi_3 \Phi_1 \Phi_2 \Phi_9 \Phi_8 - \Phi_4 \Phi_5 \Phi_7 \Phi_6$$

$$\text{genus} = 3$$
The topology of $\mathbb{T}^2$ might allow non-trivial identifications. These must be used, otherwise the tiling is inconsistent.

This results in a lower genus than expected.

**Example:** $F_0 \rightarrow$ conifold.
A complex deformation example.

- Multi-instantons are more involved. In cases where they correspond to complex deformations, they are easy to understand.
- An instanton corresponding to a complex deformation fractional brane triggers the complex deformation.
- **Example:** $dP_3 \rightarrow$ conifold.
Toric Geometry of Backreacted Dimers

- The moduli space of a genus $g$ BFT is a CY $(2g + 1)$-fold, associated to $2g$-dimensional toric diagram. For a dimer it coincides with underlying CY$_3$.

- The toric diagram of the resulting BFT is a **lift of the original one** to additional dimensions: CY$_3 \rightarrow$ CY$_{3+k}$, in general.

(Franco & Hasan, 2018)

- This geometry might be associated to an object in String Theory.
Generalizing to any BFT

- In principle, this operation can be used for general BFTs, relating ones of different genus.
- If the BFT is embedded in String Theory as a backreaction of a Dimer, the operation corresponds to a D-brane instanton.
- But, in principle, the operation is defined regardless of its interpretation in String Theory.
- One may then ask, for instance: Does it have any meaning in scattering amplitudes?
D-brane instantons in D3-branes at singularities can be understood as a combinatorial recipe in the dimer diagram.

This generically produces higher genus BFTs, providing their first physical realization.

The recipe can be generalized to arbitrary BFTs. The meaning for BFTs in other contexts is unclear.

Future avenues:

- Physical realization of higher dimensional geometry?
- Add boundaries through D7-branes. (Franco & Uranga, 2014)
- Non-Compact instantons?
- A similar story with Brane Brick Models?
Dziękuję!

(Thank You!)
EGV, & Uranga, Angel. 2017a. 
Backreacting D-brane instantons on branes at singularities. 
*JHEP, 08*, 061.

EGV, & Uranga, Angel. 2017b. 
On the 3-form formulation of axion potentials from D-brane instantons. 
*JHEP, 02*, 087.

Franco, Sebastian. 2012. 
Bipartite Field Theories: from D-Brane Probes to Scattering Amplitudes. 
*JHEP, 1211*, 141.

Franco, Sebastian, & Uranga, Angel. 2014. 
Bipartite Field Theories from D-Branes. 
*JHEP, 04*, 161.

3d printing of 2d $\mathcal{N} = (0, 2)$ gauge theories. 
*JHEP, 05*, 082.
String Theory Origin of Bipartite SCFTs. 
*JHEP*, 1305, 148.

Koerber, Paul, & Martucci, Luca. 2007. 
From ten to four and back again: How to generalize the geometry. 
*JHEP*, 08, 059.

Warped generalized geometry compactifications, effective theories and non-perturbative effects. 