From D-brane instantons to Bipartite Field Theories.

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Outline

1. Motivation and Introduction.
2. The recipe.
3. Applications.

Motivation and Introduction

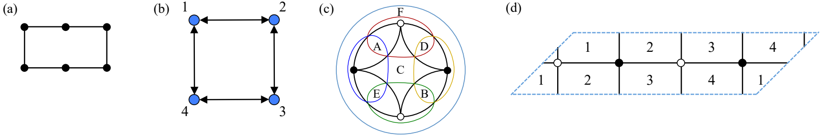
Motivation

- **Toric Field Theories** are a nice playground for relationships between Field Theory and String Theory $\rightarrow$ 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.

  $\Rightarrow$ **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.



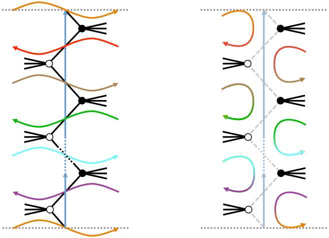
- Toric Field Theories **generalize to BFTs**, encoded in the tiling of a genus g Riemann surface.

  $\Rightarrow$ For a $g = 2$ BFT, (d) above would be a tiling of an octagon.

The Recipe

D-brane instanton in the Mirror

- 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:



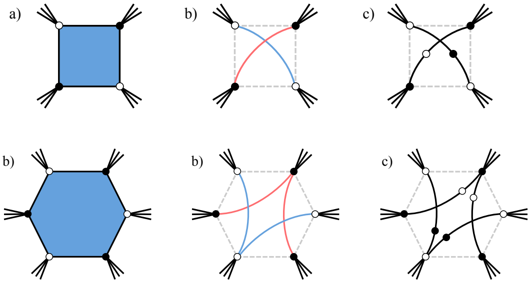
- The **genus** of the associated Dimer diagram changes as:

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

$\Rightarrow$ Generically **yields a BFT!**

D-brane instanton in the Dimer

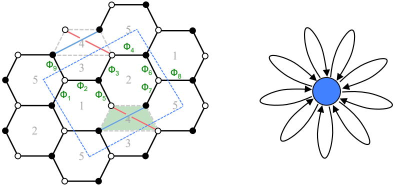
- A **D-brane instanton sits in a gauge factor**, a face in the dimer. The resulting theory is obtained by the following **recipe:**
  1. Remove the face corresponding to the instanton.
  2. Fuse the nodes colorwise, preserving ordering and introducing any necessary handles.



Applications

A couple of Examples

- An instanton on face 4 of PdP_2

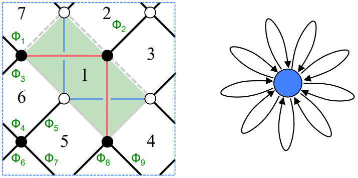


(a) (b)

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

$$genus = 2$$

- An instanton on face 1 of PdP_4



(a) (b)

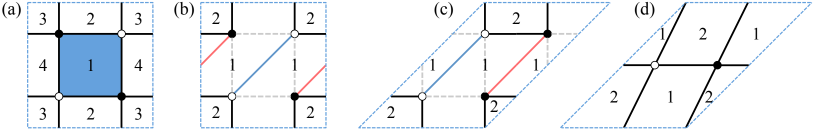
$$W = \Phi_5\Phi_4\Phi_3\Phi_8\Phi_7 + \Phi_2\Phi_1\Phi_6\Phi_9 -$$
$$-\Phi_3\Phi_1\Phi_2\Phi_9\Phi_8 - \Phi_4\Phi_5\Phi_7\Phi_6$$

$$genus = 3$$

$\Rightarrow$ The obtained BFT's have the **same quiver but different genus!** The superpotential is different.

An example with lower genus.

- 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:** $F_0 \to$ conifold.

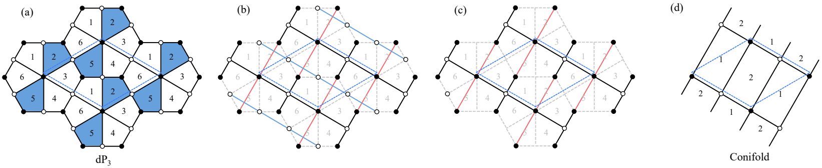


F_0 phase 1

Conifold

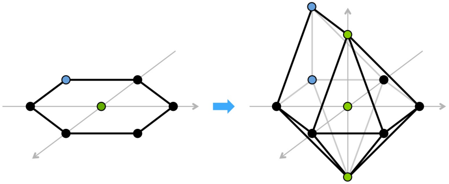
A complex deformation example.

- 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: $CY_3 \to CY_{3+k}$, in general.

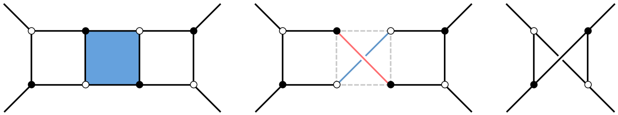


(Franco & Hasan, 2018)

- 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?**



Conclusions & Outlook

- **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.

Franco, Sebastin, & Hasan, Azeem. 2018.
$3d$ printing of $2d$ $\mathcal{N} = (0, 2)$ gauge theories.
JHEP, **05**, 082.

Heckman, Jonathan J., Vafa, Cumrun, Xie, Dan, & Yamazaki, Masahito. 2013.
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.

Koerber, Paul, & Martucci, Luca. 2008.
Warped generalized geometry compactifications, effective theories and non-perturbative effects.
Fortsch. Phys., **56**, 862–868.