Deformations of Dimers with Orientifolds

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Work in Progress
by A.R. & A. Uranga

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CSIC Consejo Superior de Investigaciones Científicas

Gauge/gravity correspondence

Everything started with the Maldacena conjecture:

Consider a stack of N D3-branes *on flat space-time* in Type IIB String Theory

- Open string description
- Supergravity description

$$ds^2 = Z(r)^{-1/2}\eta_{\mu\nu}dx^\mu dx^\nu + Z(r)^{1/2}(dr^2 + r^2 ds^2_{S^5})$$

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- Supergravity description $(R^4 \sim N)$

$$ds^2 = Z(r)^{-1/2}\eta_{\mu\nu}dx^\mu dx^\nu + Z(r)^{1/2}(dr^2 + r^2 ds^2_{S^5})$$

$$\rightarrow \left(\frac{r^2}{R^2}\eta_{\mu\nu}dx^\mu dx^\nu + \frac{R^2}{r^2}dr^2\right) + R^2 ds^2_{S^5} = ds^2_{AdS_5} + R^2 ds^2_{S^5}$$

Gauge/gravity correspondence

What if we put the D3-branes on a singularity (a cone)?

$$\mathbb{R}^6 = \mathbb{R}^+ \times S^5 \to Y_6 = \mathbb{R}^+ \times X_5$$

$$ds^2 \to ds^2_{AdS_5} + R^2 ds^2_{X_5}$$

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But unknown Superpotential (Y_6 is Calabi-Yau $\to$ SUSY)

Gauge/gravity correspondence

An early example by Klebanov-Witten

They considered $Y_6 =$ conifold $\quad (xy = zw;\ x, y, z, w \in \mathbb{C})$

$\Rightarrow$ Gauge theory is $\mathcal{N} = 1$ $SU(N) \times SU(N)$ and has chiral multiplets A_1 , A_2 in the ($\square$, $\overline{\square}$) & B_1 , B_2 in the ($\overline{\square}$, $\square$)

Superpotential???

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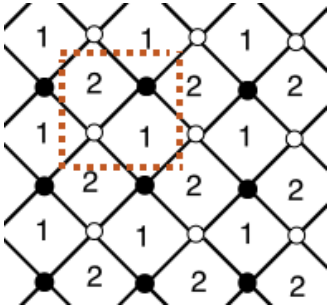
Superpotential??? $\qquad W = \mathrm{Tr}\, A_1 B_1 A_2 B_2 - \mathrm{Tr}\, A_1 B_2 A_2 B_1$

It turns out that if the singularity is **TORIC**, the superpotential is also given. Furthermore, all the information can be encoded in a **DIMER** diagram. Franco-Hanany-Kennaway-Vegh-Wecht

Dimers I: Introduction

For the conifold



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- They are bi-periodic: unit cell is a $\mathbf{T}^2$

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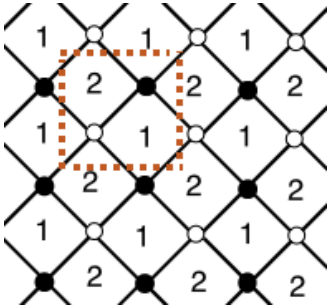

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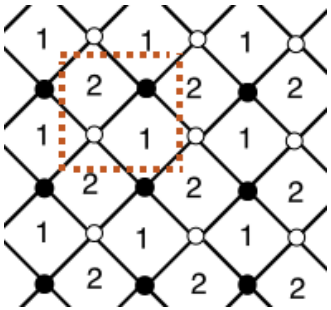

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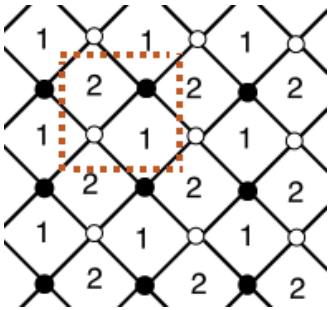

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- Vertices $=$ Superpotential terms

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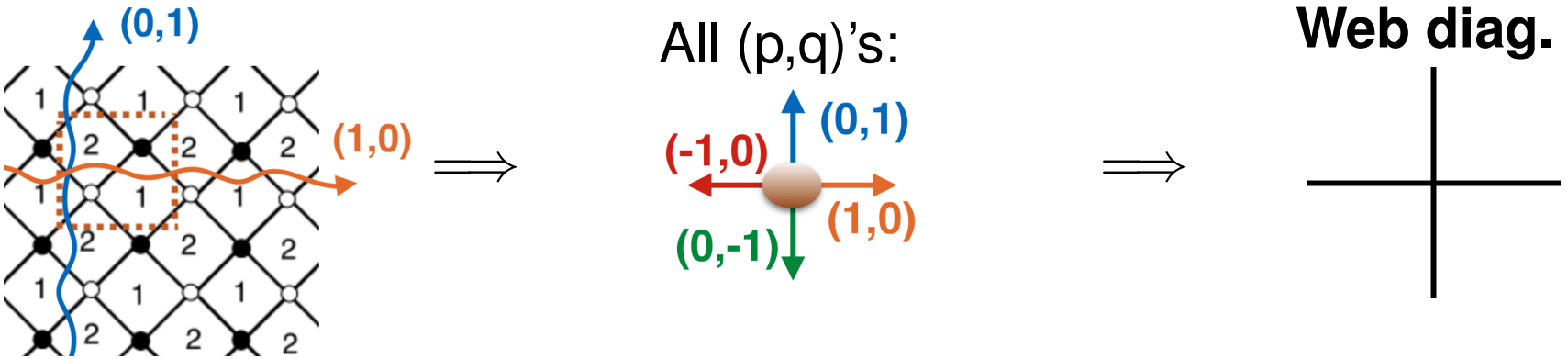
and $W = \mathrm{Tr}\, A_1 B_1 A_2 B_2 - \mathrm{Tr}\, A_1 B_2 A_2 B_1$

Dimers II: Zig-zag paths & Web diagrams

Def: Zig-zag (paths) are paths crossing edges and turning maximally to the right on e.g white vertices and to the left on black ones. Kenyon ; Kenyon-Schlenker ; Hanany-Vegh

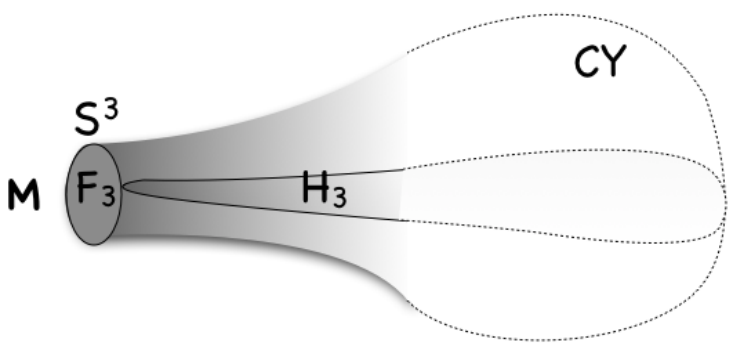


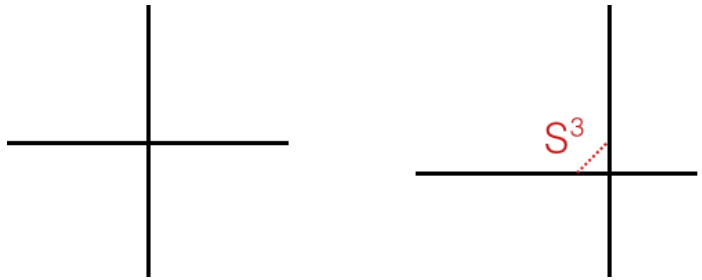
Web diagrams are well known in math literature.
Each toric singularity = one web diagram.

(Complex) Deformations I

The Klebanov-Strassler solution:
Add fluxes in SUGRA solution such that they hold an S^3 on the bottom of the throat with finite size (=**DEFORMED** conifold)

$$\frac{1}{2\pi\alpha'}\int_A F_3 = 2\pi M \quad ; \quad \frac{1}{2\pi\alpha'}\int_B H_3 = 2\pi K$$

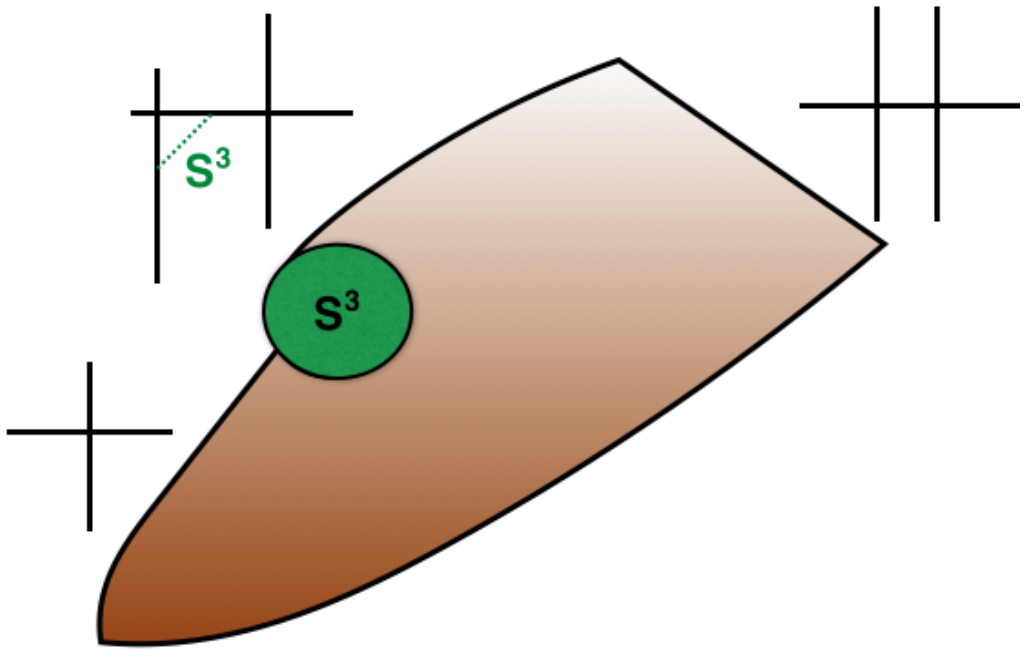




Useful for e.g. creating hierarchies *a-la* Randall-Sundrum in ST.
Giddings-Kachru-Polchinski ; H. Verlinde

(Complex) Deformations II

The deformation idea is more general: we can consider conical singularities with a base X_5 that at certain point at the cone have an S^3 such that for lower radii the base of the cone changes.



Separate into sub-webs in equilibrium Aganagic-Vafa

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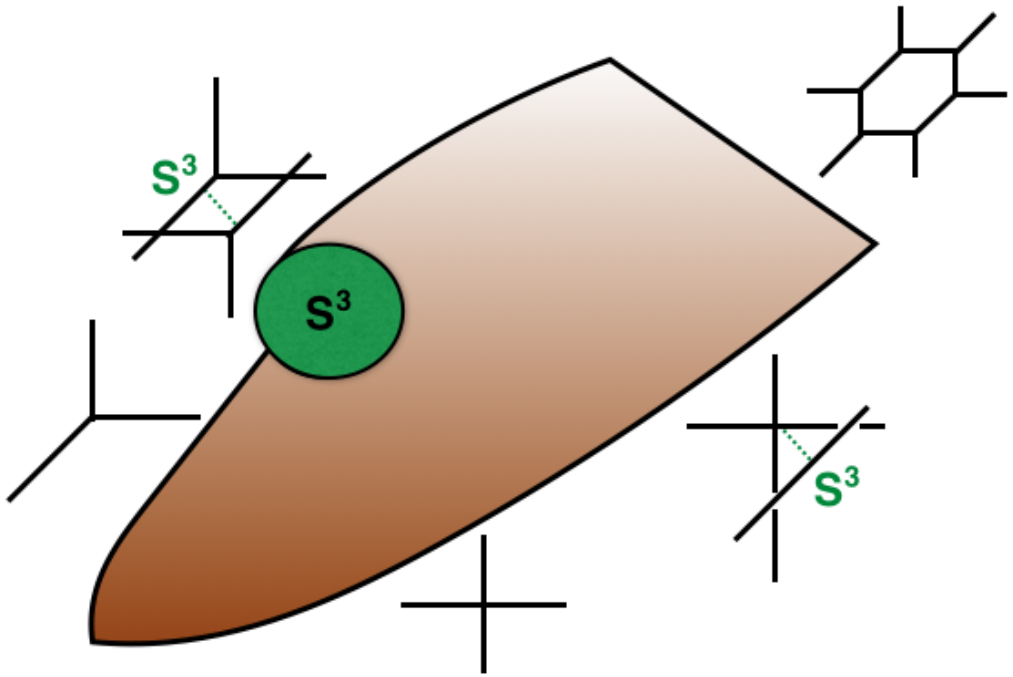

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Orientifolds of Dimers

An orientifold of a theory $\sim$ Quotient by $\Omega = \mathcal{R}(...)$
where $\mathcal{R}$ inverts some spatial coordinates $\mathcal{R} : x^i \to -x^i$

For a dimer, we can have two kinds of orientifolds
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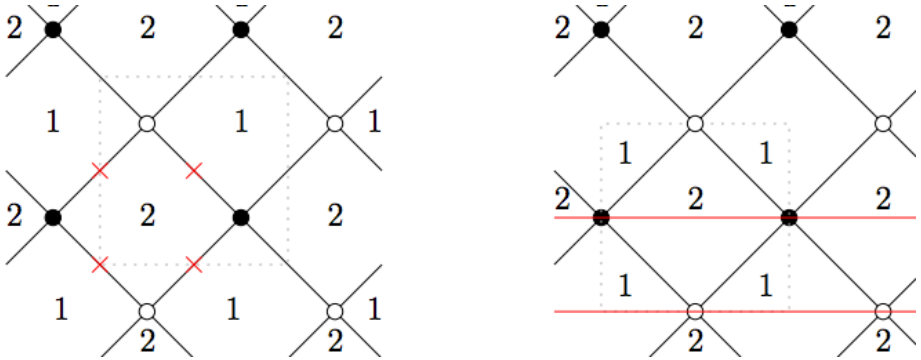

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- Restrictions from SUSY

Why interesting? SO & Sp groups, matter in (anti)symmetric ...

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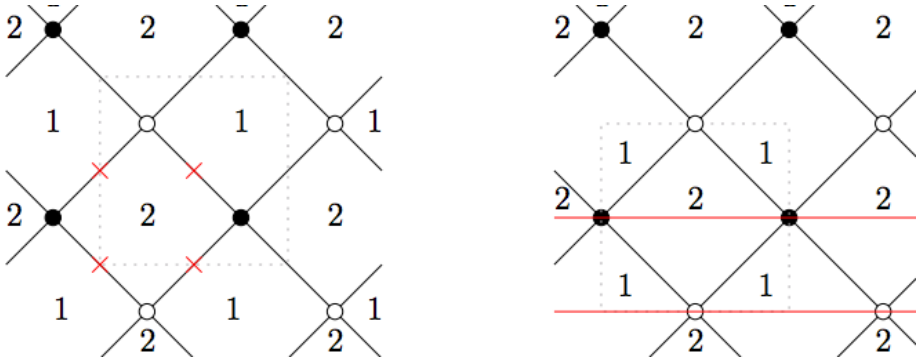

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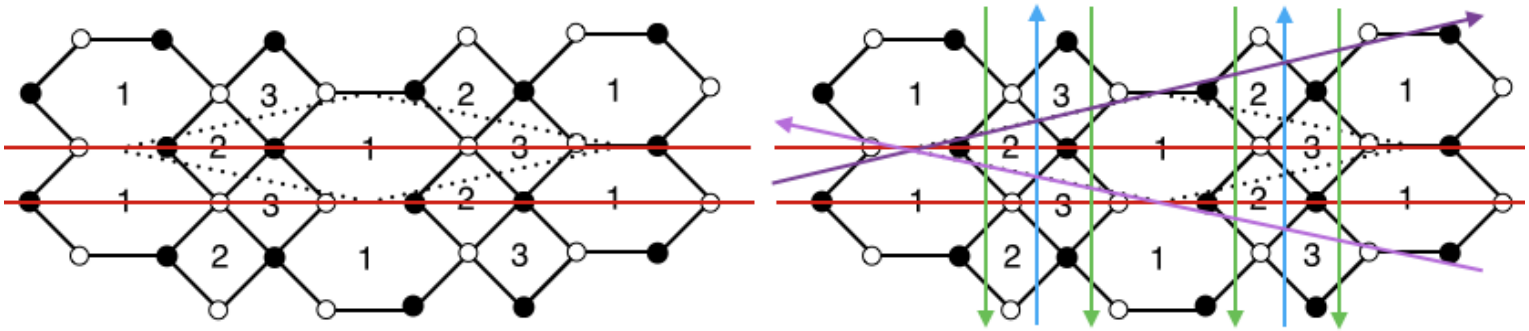
Which singularities accept orientifolds AND deformations?

Orientifold lines I: Criteria

Consider for example the dimer of L^{121}:



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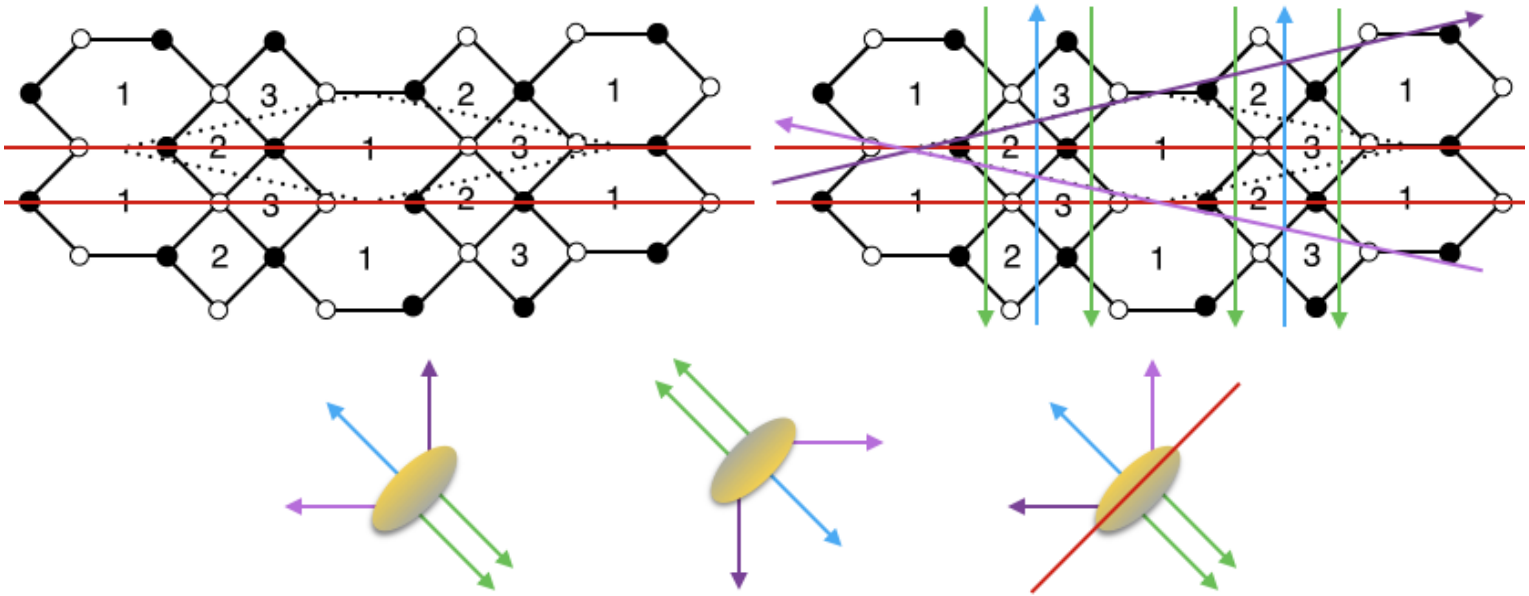

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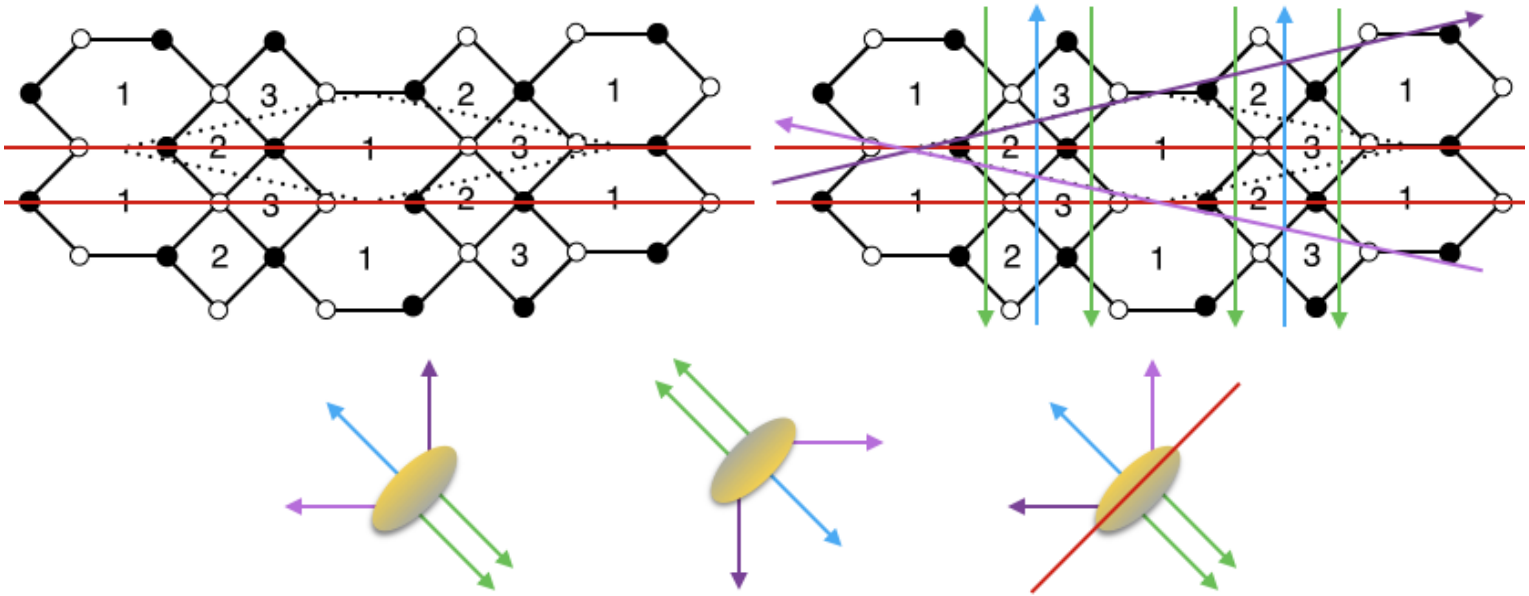

Web diagram is $\mathbb{Z}_2$ symmetric w.r.t. a line $\Leftrightarrow$ **Dimer accepts orientifold line**

Orientifold lines II: Deformations

Deformation $=$ Removal of a sub-web in equilibrium

Orientifold line $\Leftrightarrow$ Line $\mathbb{Z}_2$ symm. of web diagram

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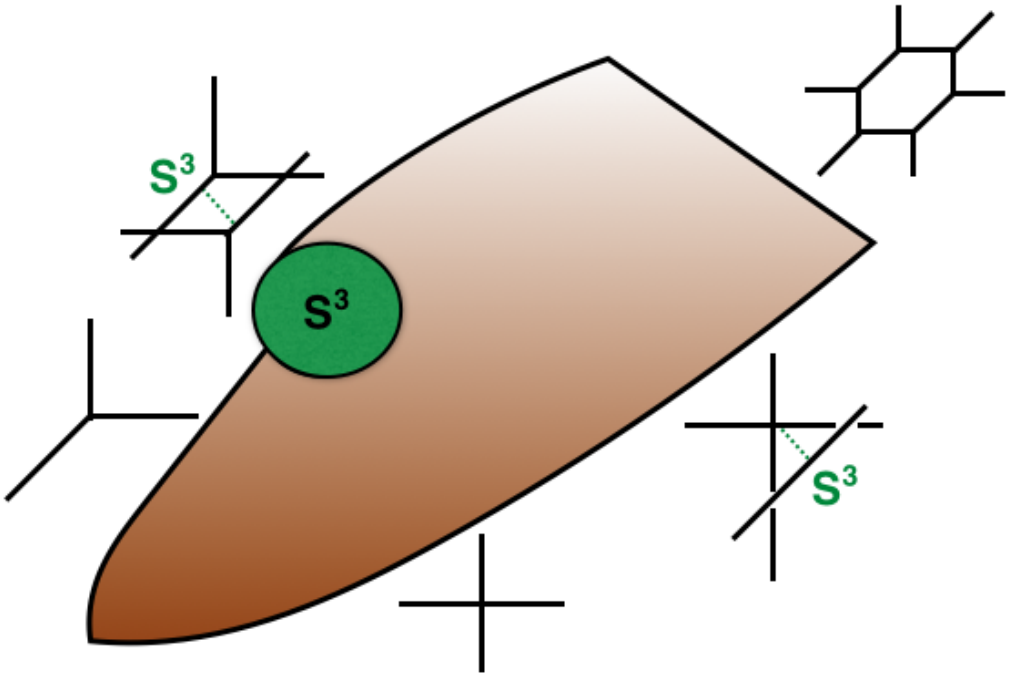
$\Downarrow$

Deformations with orientifolds possible $\Leftrightarrow$ **UV web, IR web & removed sub-web are invariant under the same $\mathbb{Z}_2$ line action**

Orientifold lines II: Deformations

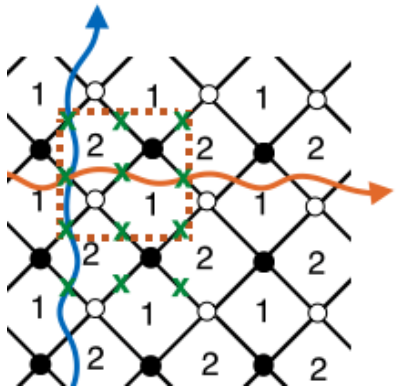
An example: Possible deformation of an orientifold line over dP_3



Only the transition to the orientifold of the conifold is possible

Orientifold points I: Criteria(?)

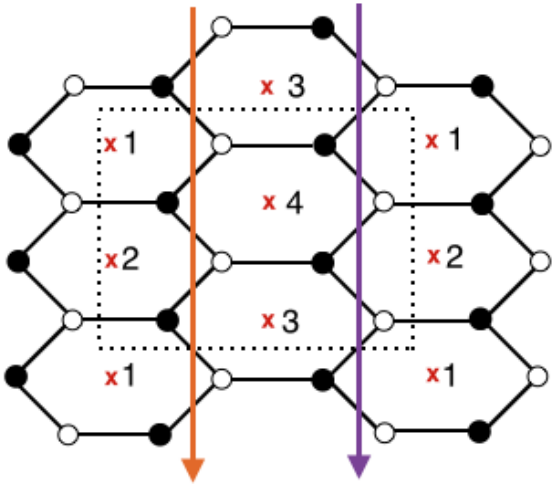
Unfortunately, web diagrams cannot tell us which singularities accept orientifold points.

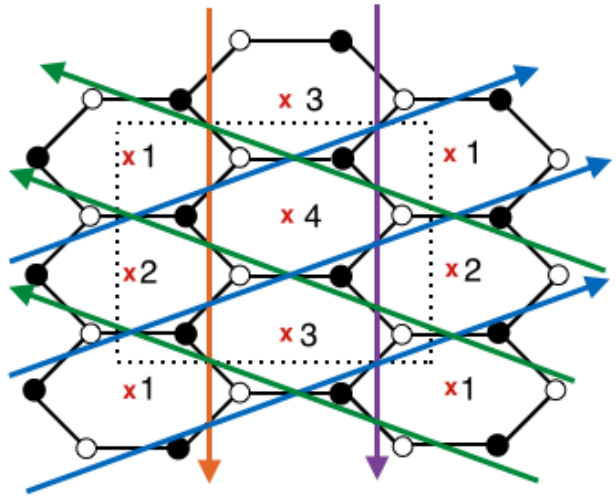


There is still some work to do...

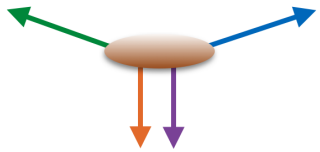
Orientifold points II: Deformations

No *complete* criterium yet. Consider the following dimer:





It has two parallel zig-zags that are images of one another



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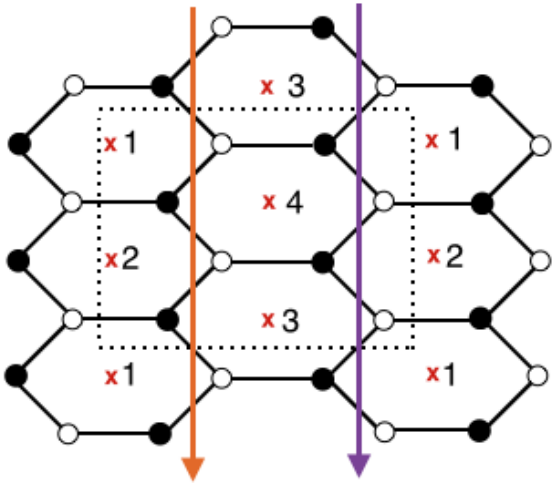
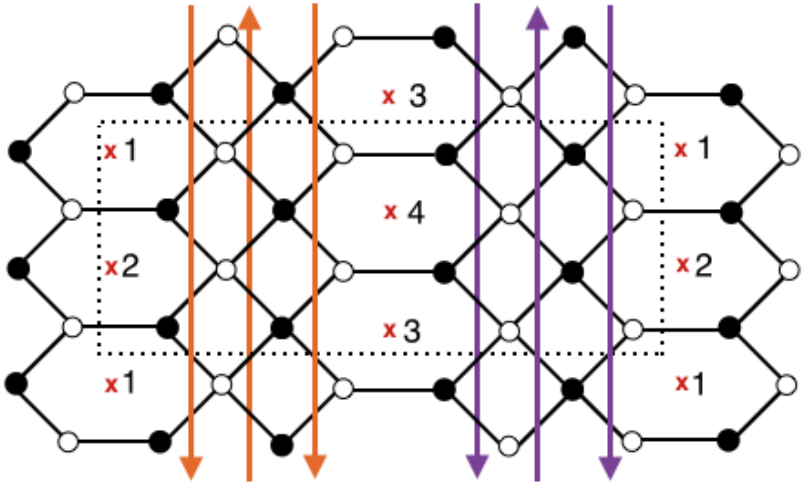
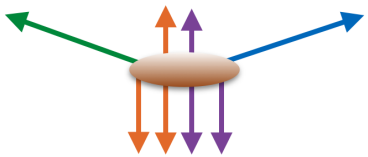




We can add two double columns of rhombi (four parallel zig-zags)



Applications

Set-ups of orientifolds of dimers with deformations have recently shown up for different purposes:

- "*D-brane Instantons as Gauge Instantons in Orientifolds of Chiral Quiver Theories*", S. Franco, A. R. and A. Uranga.
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Thank You!