Landau-Ginzburg Orbifolds and their Symmetries

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Motivation

The Landau-Ginzburg Orbifold

'The internal manifold is just a point'

- Quasi exact solvable, flow to exact CFT's in the IR
  '*The lagrangian describtion of minimal model CFTs*'
- Describe consistent heterotic compactifications
- Instantons are switched off
- Duals of Calabi-Yau compactifications

Interesting playgrounds to study

1. The heterotic moduli space [Gepner,Aspinwall,Melnikov,Plesser...]
2. Model building [Font,Ibanez,Quevedo,Schellekens,Blumenhagen,Weigand...]
3. Mirror symmetry
   [Greene,Plesser,Adams,Basu,Lerche,Warner,Candelas,Kreutzer,Sethi,Schimmrigk,Skarke,Blumenhagen,Wisskirchen,Flohr, Rahn..]
4. Engineer hybrid CFT's [Bertolini, Melnikov, Plesser '13]
5. Selection rules in heterotic compactifications [Gepner,Chun, Mas, Lauer, Nilles,Aspinwall,Plesser,Diestler,Kachru...]

Outline

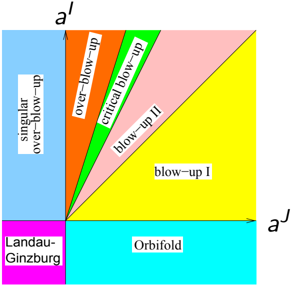
- Motivation
- The Landau Ginzburg Spectrum
- Classification of A_1^9 Gepner models
- Matching LGO symmetries with geometric Dual
- Summary and conclusions

Phases of Gauged Linear Sigma Models

Consider **two dimensional field theory** that exhibits

- (2,2) with chiral multiplets $\Phi^i = \phi^i + \theta_\alpha \gamma^{i,\alpha} + \theta^2 F^i$
- Exhibits a $U(1)_L \times U(1)_R$ R-symmetry and additional gauged U(1)'s [Witten'93]
- The U(1) charges **constraint** by **2D anomalies**
  $\rightarrow$ CY condition for target space manifold [See Hans Jockers talk]

$$\mathcal{L} = \int d\theta^4 K(\Phi, \overline{\Phi}, \Psi, \overline{\Psi}) + \int d\theta^2 \Psi^I \cdot \hat{\mathcal{W}}(\Phi)_I + \text{FI-terms}(a^K)$$



[Blaszczyk,Groot Nibbelink,Rühle'11]

The Landau-Ginzburg Orbifold Phase

- with $a^j < 0$, $|\psi^j| \neq 0$
  $\rightarrow$ U(1)'s broken to $\mathbb{Z}_\mathbf{N}$ Symmetry
- F-& D-Term equation:

target space shrinks to a point

Landau-Ginzburg Generalities

Defining properties and constraints

- The quasi homogenous Superpotential: $\hat{\mathcal{W}}(\kappa^{Q_0}\Phi^i) = \kappa\hat{\mathcal{W}}(\Phi^i)\,, \quad 0 < Q_0 \leq 1$
- Flows to CFT in IR with right central charge:

$$c = 3\sum_i (1 - 2Q_0^i) \stackrel{!}{=} 9$$

- Possesses a $\mathbb{Z}_{N_0} \times .. \times \mathbb{Z}_{N_n}$ symmetry

Defining a discrete quotient

Assign charges to fields ϕ $\vec{Q}_i \in \mathbb{Z}_{N_i}$ to mod them out

- Q_0^i World sheet R-charge
- $\sum_i Q_a^i = 0 \quad \forall a > 0 \rightarrow$ Anomaly free $\mathbb{Z}_{N_a}$ discrete Symmetry

- Add 10 Mayorana Weyl Fermions $\lambda^I \& E_8$ current algebra.
- Combined GSO and Orbifold projection: $g = e^{-i(\pi Q_0 + \lambda)}\,, e^{2\pi i Q^i}$
  We get twisted sectors

LGO-Spectrum

Twisted Modding

$$\phi^i(\sigma + 2\pi) = e^{-i\pi k Q^i}\phi^i(\sigma)$$

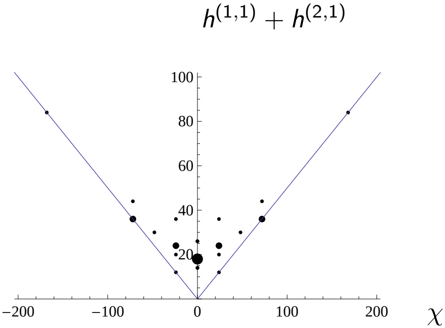
$\rightarrow$ twisted Vacuum (Energie, q_i, q_R charges) $|g^k, \vec{Q}_i\rangle$ [Kachru, Witten'93]

- 4D theory has additional U(1)'s, with charges q_i of world sheet fields with $q_L = \sum_i q_i$
- Govern **gauge representation**: $E_6 \supset SO(10) \times U(1)_L$:

$$\mathbf{78} \rightarrow \mathbf{45}_0 \oplus \mathbf{16}_{-3/2} \oplus \overline{\mathbf{16}}_{3/2} \oplus \mathbf{1}_0$$
$$\mathbf{27} \rightarrow \mathbf{16}_{-1/2} \oplus \mathbf{10}_1 \oplus \mathbf{1}_2$$

- The $U(1)_R$ charge specifies the space-time Lorentz representation

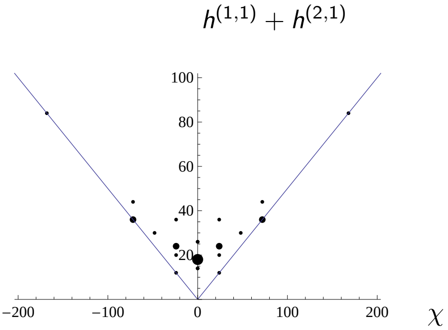
$(A_1)^9$ Fermat Classification



The classification

We **systematically** constructed all Abelian orbifolds of the $(A_1)^9$ Gepner model and computed the whole massless matter spectrum

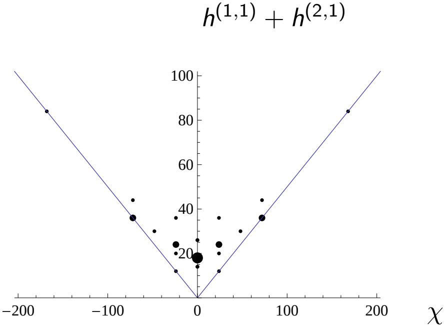
$(A_1)^9$ Fermat Classification



Mirror Symmetry

The set of models is closed under **Mirror Symmetry** [Greene, Plesser]
Acquire the Mirror Model by orbifold by the maximal subgroup!

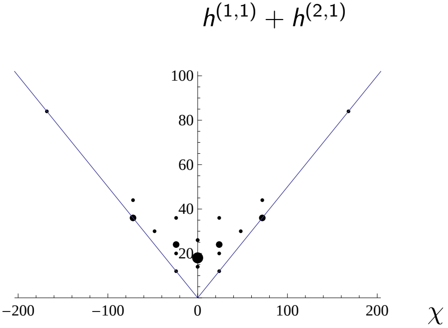
$(A_1)^9$ Fermat Classification



Most (geometric) models have Orbifold phase: [Fischer,Ratz,Torrado,Vaudrevange'12]

$\mathcal{N}$	$h^{(1,1)}$	$h^{(2,1)}$	Add Gauge Group	Add Singlets	Geometric Phase
1	36	0	$U(1)^6 \times SU(3)$	270	$T^6/\mathbb{Z}_3$
1	12	0	$U(1)^8$	252	$T^6/(\mathbb{Z}_3 \times \mathbb{Z}_{3,\text{free}})$
1	9	9	$U(1)^6 \times SU(3)$	270	?
2	21	21	$U(1)^6 \times SU(3)$	194	$T^2 \times K3$
4	9	9	$E_6 \times SU(3)$	258	T^6

$(A_1)^9$ Fermat Classification



Observations

- The additional vector multiplets
  $\hookrightarrow$ Gauged isometries of self dual point
- **Some Numerology:**
  $\#_{\text{Singlets}} - 3 \cdot \#_{\text{Add-Vectors}} = (4 - \mathcal{N})76$

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Matching with $T^6/\mathbb{Z}_3$

[Aspinwall, Plesser'10]

$\boxed{\widehat{T^6/\mathbb{Z}_3}}$ **Fermat LGO** $(h^{1,1}, h^{2,1}) = (0, 36)$ $\overset{\text{Mirror Symmetric}}{\longleftrightarrow}$ $\boxed{T^6/\mathbb{Z}_3}$ **Fermat LGO** $(h^{1,1}, h^{2,1}) = (36, 0)$

The Additional Singlet and Vector Spectrum

Singlet	q_1	q_2	q_r
U	0	1	0
	-1	0	0
	1	-1	0
B	$\frac{1}{3}$	0	$-\frac{1}{3}$
	0	$-\frac{1}{3}$	$-\frac{1}{3}$
	$-\frac{1}{3}$	$\frac{1}{3}$	$-\frac{1}{3}$

Symmetries:

- 8 Vectors $\rightarrow$ Adjoint of SU(3)
- $(U(1) \times U(1) \ltimes S_3)^3$
- Discrete R-Symmetry [Distler,Kachru]
- $q_r = (3 \underbrace{k_0}_{\text{Twist}} - 2q_L + \underbrace{q_s}_{\text{Strangeness}})/18 \text{ mod } 1$

  with $q_r(\mathcal{W}) = 1/3$

Matching with $T^6/\mathbb{Z}_3$

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$(h^{1,1}, h^{2,1}) = (0, 36)$		$(h^{1,1}, h^{2,1}) = (36, 0)$
$\downarrow$ C.S. Deformation		$\downarrow$ Kähler Deformation
$\widehat{T^6/\mathbb{Z}_3}$ **non-Fermat LGO**		$T^6/\mathbb{Z}_3$ **Orbifold**

The Additional Singlet and Vector Spectrum

Singlet	q_1	q_2	q_r
$\langle U \rangle$	0	1	0
	-1	0	0
	1	-1	0
	$\frac{1}{3}$	0	$-\frac{1}{3}$
	0	$-\frac{1}{3}$	$-\frac{1}{3}$
	$-\frac{1}{3}$	$\frac{1}{3}$	$-\frac{1}{3}$

Symmetries:

- 8 Vectors $\rightarrow$ Adjoint of SU(3)
- $(\mathbb{Z}_3 \times \mathbb{Z}_3 \ltimes S_3)^3 = \Delta(54)^3$ [Beye,Kobayashi,Kuwakino'14]
- Discrete R-Symmetry [Distler,Kachru]
- $q_r = (3 \underbrace{k_0}_{\text{Twist}} - 2q_L + \underbrace{q_s}_{\text{Strangeness}})/18 \mod 1$

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Matching with $T^6/\mathbb{Z}_3$

[Aspinwall, Plesser'10]

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$\downarrow$ C.S. Deformation		$\downarrow$ Kähler Deformation
$\widehat{T^6/\mathbb{Z}_3}$ **non-Fermat LGO**		$T^6/\mathbb{Z}_3$ **Orbifold**
$\downarrow$ C.S. Deformation		$\downarrow$ Kähler Deformation
$\widehat{T^6/\mathbb{Z}_3}$ **non-Fermat LGO**		**Smooth CY**

The Additional Singlet and Vector Spectrum

Singlet	q_1	q_2	q_r
$\langle U \rangle$	0	1	0
	-1	0	0
	1	-1	0
$\langle B \rangle$	$\frac{1}{3}$	0	$-\frac{1}{3}$
	0	$-\frac{1}{3}$	$-\frac{1}{3}$
	$-\frac{1}{3}$	$\frac{1}{3}$	$-\frac{1}{3}$

Symmetries:

- ~~8 Vectors $\rightarrow$ Adjoint of SU(3)~~
- ~~$(\mathbb{Z}_3 \times \mathbb{Z}_3 \times S_3)^3 = \Delta(54)^3$~~ [Beye,Kobayashi,Kuwakino'14]
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  with $q_r(\mathcal{W}) = 1/3$

Summary and conclusion

$$\begin{array}{ccc} \text{CICY} & \xrightarrow{\text{Kähler Def.}} & \text{LGO} \\ \uparrow & & \downarrow \text{ Mirror} \\ \text{Def. LGO} & \xleftarrow{\text{C.S. Def.}} & \text{Mirror LGO} \end{array}$$

Track Symmetries through various phases

I.e. track **Flavor and R-symmetries** to

- Orbifold Phase
- Large Volume Calabi-Yau phase

Works whenever we have a GLSM description of a CY (i.e. CICY)

Exhaustive Scan of all $(A_1)^9$ Gepner Models

Constructed the whole vector and singlet Spectrum

- Orbifold Match: Compactification at **self dual radius**
- Models with $\mathcal{N} = 1, 2, 4$ Susy
- A mysterious relation satisfied by all models

Thank You!