# D-branes on T-folds with few T's 

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## Foreword

- Most mechanisms of moduli stabilization require (R-R) fluxes that are poorly understood in string theory
- Yet, in asymmetric orbifolds or alike, chiral twists freeze untwisted moduli, non-geometric shifts prevent massless twisted moduli [Dabholkar, Hull; Dine, Silverstein; Kumar, Vafa; .....B., Morales, Pradisi]
- The combined effect of twists and shifts has not been systematically explored in the context of unoriented strings
- Expect duality between (D-branes in) non-geometric vacua and (D-branes in) flux compactifications, at least for extended susy $(\mathcal{N} \geq 3)$


## Plan

Part I: Unoriented twists and shifts [Anastasopoulos, MB, Morales, Pradisi (w.i.p.)]

- Unoriented T-folds with few T's
- Two simple examples based on

$$
\begin{aligned}
& T_{S O(12)}^{6} / Z_{2}^{L} \times Z_{2}^{R} \times Z_{2}^{\prime} \times Z_{2}^{\prime R}: \\
& -" h_{11} "=" h_{21} "=1 \text { (self-mirror) } \\
& -" h_{11} "=0, " h_{21} "=6 \text { and its "mirror" (discrete torsion) }
\end{aligned}
$$

- Partial moduli stabilization, rank reduction, non-chiral ...

Part II: Bound-states of D-branes in L-R asymmetric vacua
[MB]

- Residual susy and R-R couplings
- $\mathcal{N}=6=2_{L}+4_{R}$ and other extended susy cases
- Open string excitations

Outlook and Announcements

## Part I: Unoriented twists and shifts

## Unoriented T-folds with few T's

CDMP model [Camara, Dudas, Maillard, Pradisi; Vafa, Witten]: standard geometric freely acting orbifold $T^{6} / Z_{2} \times Z_{2}$, Type I / Heterotic dual pairs All twisted moduli are massive. Only untwisted moduli $T_{l}, U_{l}$, Combine with gaugino condensate(s) in open string sector and/or 3-form fluxes to partially stabilize dilaton and other moduli.
DJK 'minimal' model [Dolivet, Julia, Kounnas]: (non-magic) hyper-free model, fermionic construction

$$
G=\psi^{\mu} \partial X_{\mu}+\chi^{i} y^{i} w^{i}
$$

Fermionic basis sets [Antoniadis, Ellis, Hageliin, Nanopoulos; ... Faraggi, Kounnas; ...] :
$F, S, \bar{S}, \bar{b}_{1}, b_{1}=\left\{\psi^{\mu}, \chi^{1,2} ; y^{3,4,5,6}, y^{1} w^{1} \mid \bar{y}^{5} \bar{w}^{5}\right\}$,
$b_{2}=\left\{\psi^{\mu}, \chi^{3,4} ; y^{1,2}, w^{5,6} y^{3} w^{3} \mid \bar{y}^{6} \bar{w}^{6}\right\}$,
$b_{3}=\left\{\psi^{\mu}, \chi^{5,6} ; w^{1,2,3,4} y^{6} w^{6} \mid \bar{y}^{6} \bar{w}^{6}\right\}$
Only dilaton vector-multiplet survives. $\mathcal{N}_{L}=0$, L-R asymmetric $(-)^{F_{L}}$ freely acting orbifold of $T_{S O(12)}^{6}, y^{i} w^{i} \approx$ shifts.

## Combining DJK and CDMP

Replace $\bar{b}_{3}$ with $b_{2}$, get a L-R symmetric asymmetric orbifold. Geometric (freely acting) projections associated to $b_{1} \bar{b}_{1}$ and $b_{2} \bar{b}_{2}$. Non geometric (freely acting) projections associated to $b_{1}, b_{2}, \ldots b_{1} \bar{b}_{2}$.
All untwisted moduli except dilaton hypermultiplet are projected out $\left(\mathcal{N}_{L}=\mathcal{N}_{R}=1, \mathcal{N}_{\text {tot }}=2\right)$.
Massless multiplets only from $b_{1} b_{2} \bar{b}_{1} \bar{b}_{2}$ twisted sector: one hyper and one vector, " $h_{11}$ " $=$ " $h_{21} "=1\left(\mathcal{H O} \mathcal{L} \mathcal{G} \mathcal{R} \mathcal{A} \mathcal{L}\right.$ [Szendroi, Gross] $\left.^{\prime}\right)$ Unoriented projection produces $1_{u}+2_{t}-n$ chiral-plets and $n$ vector-plets $(n=0,1)$
Open string spectrum: non chiral, rank reduction from B-field. Systematic study under way. For MSSM embeddings [Kiritisis, Schellekens] Combine with (non) anomalous $U(1)$ 's, fluxes, (non)geometric D-brane instantons (gaugino condensation, ADS-like
superpotentials, ...) [Blumenhagen's, Dudas's, Cvetic's talks]
$T^{6} /\left(Z_{2 L} \times Z_{2 L}^{\prime} \times Z_{2 R} \times Z_{2 R}^{\prime}\right)$ model with " $h_{11}$ " $=$ " $h_{21}$ " $=1$

Generators of the orbifold group specified by the fermionic sets

$$
\begin{aligned}
& g_{1}=\left\{\chi_{3456} ; y_{13456} ; \quad w_{1} \mid \quad ; \quad \tilde{y}_{5} ; \quad \tilde{w}_{5}\right\} \\
& g_{2}=\left\{\chi_{1256} ; \quad y_{123} ; w_{356} \mid \quad ; \quad \tilde{y}_{6} ; \quad \tilde{w}_{6}\right\} \\
& \tilde{g}_{1}=\left\{\quad ; \quad y_{5} ; w_{15} \mid \tilde{\chi}_{3456} ; \quad \tilde{y}_{13456} ; \quad \tilde{w}_{1}\right\} \\
& \tilde{g}_{2}=\left\{\quad ; \quad y_{6} ; \quad w_{6} \left\lvert\, \begin{array}{c}
\left.\tilde{\chi}_{1256} ; \quad \tilde{y}_{123} ; \quad \tilde{w}_{356}\right\}
\end{array}\right.\right.
\end{aligned}
$$

Introducing

$$
\begin{aligned}
& g_{3}=g_{1} g_{2}=\left\{\chi_{1234} ; \quad y_{2456} ; w_{1356} \mid \quad ; \quad \tilde{y}_{56} ; \tilde{w}_{56}\right\} \\
& \tilde{g}_{3}=\tilde{g}_{1} \tilde{g}_{2}=\left\{\quad ; \quad y_{56} ; \quad w_{56} \mid \tilde{\chi}_{1234} ; \quad \tilde{y}_{2456} ; \tilde{w}_{1356}\right\}
\end{aligned}
$$

the generic orbifold group element can be written as $g_{m}^{a} \tilde{g}_{n}^{b}$ with $m, n=1,2,3, a, b=0,1$.

Torus partition function

$$
\mathcal{T}=\frac{1}{16} \sum_{a, b, c, d=0}^{3} \rho_{a c} \bar{\rho}_{b d} \boldsymbol{\Lambda}_{a b, c d}
$$

with $\rho_{a b}$ chiral orbifold amplitudes and $\boldsymbol{\Lambda}_{a b, c d}$ invariant (sub)lattices of $S O$ (12)
Only massless states come from the $g_{3} \tilde{g}_{3}$-twisted sector:

$$
\mathcal{T}=|V-S-C|^{2}+|2 O-S-C|^{2}+\ldots
$$

$\mathcal{N}=2$ supergravity coupled to $1+1$ hypers and 1 vector $" h_{11} "=" h_{21} "=1, " \chi "=0$ (self-mirror) !!

## Unoriented projection and open strings

Klein bottle projection

$$
\begin{aligned}
\mathcal{K} & =\frac{1}{32} \sum_{a, b, c=0}^{3} \operatorname{Tr}_{g_{a} \tilde{g}_{a}} \Omega g_{b} \tilde{g}_{c}(q \bar{q})^{H_{c l}}=\frac{1}{8} \sum_{a, d=0}^{3} \operatorname{Tr}_{g_{a} \tilde{g}_{a}} \Omega \hat{g}_{d}(q \bar{q})^{H_{c l}} \\
& =\frac{1}{8} \sum_{a, d=0}^{3} \rho_{a, d} \hat{\Lambda}_{a, d}\left(2 \tau_{2}\right)
\end{aligned}
$$

only 64 'effective' characters $\hat{g}_{a}: S O(12) \rightarrow S O(4)^{2} \times S O(2)^{2}$ Transverse channel $\tilde{\mathcal{K}} \approx \chi_{1}$ (identity), as a consequence $\tilde{\mathcal{M}}=\hat{\chi}_{1}$ and the Möbius-strip projection is simply

$$
\mathcal{M}=+\hat{\chi}_{1}-\hat{\chi}_{4}-\hat{\chi}_{5}-\hat{\chi}_{8}
$$

Symplectic Chan-Paton group, tadpole condition $\operatorname{Sp}(1)^{8}$ with uninteresting non-chiral matter

## Intermezzo: B-field and no vector structure

Most 'rational' models allow/require discrete non zero values for the 'frozen' moduli
B-field in Type I, odd under $\Omega, B=1 / 2$ allowed, rank reduction in toroidal compactifications with flat bdles (susy) $N=32 \times 2^{-r_{B} / 2}$
[MB, Sagnotti; MB, Pradisi, Sagnoti], for $S O(12) r_{B}=4$
Heterotic dual description: CHL strings [Chaudhuri, Hockney, Lykken]
Compactifications without vector structure $B=\tilde{w}_{2}$, non commuting Wilson lines [Sen, Sethi; Berkooz et al; MB; Witten; Dijkgraaf et al]
For non-susy (non-tachyonic) toroidal models with magnetic fields and 't Hooft fluxes, rank reduction not necessary Model C ${ }_{\text {[Bachas] }} G=U(5) \times U(3) \times U(4) \times U(4)^{\prime}$ with (5*,3) and 3 copies of 10. Non susy. Magnetic field without vector structure, requires non zero B-field for consistency [Bachas, MB, Blumenhagen, Lüst, Weigand]
$T^{6} /\left(Z_{2 L} \times Z_{2 L}^{\prime} \times Z_{2 R} \times Z_{2 R}^{\prime}\right)$ model with " $h_{21}$ " $=6$, " $h_{21}$ " $=0$ and its mirror

Generators of the orbifold group specified by the fermionic sets

$$
\left.\begin{array}{rlrl|lll}
g_{1}^{\prime} & = & \left\{\chi_{3456} ;\right. & y_{1235} ; & w_{1246} \mid & ; & \tilde{y}_{35} ; \\
g_{2}^{\prime} & = & \chi_{1256} ; & y_{2346} ; & w_{1345} & \tilde{w}_{35}
\end{array}\right\}
$$

All 'geometric' twisted sectors $g_{a} \tilde{g}_{a}$ contribute massless states, depending on discrete torsion $\epsilon= \pm 1$

- $\epsilon=+1: 6=3 \times 2$ vector multiplets
- $\epsilon=-1: 6=3 \times 2$ hyper multiplets


## Including open and unoriented strings

Klein bottle projection, similar to previous case, yet $\hat{g}_{a}^{\prime}: S O(12) \rightarrow S O(4)^{4}$.
In the transverse channel $\tilde{K} \approx \chi_{1}+$ massive.
(So far) only viable possibility: $\tilde{M} \approx \hat{\chi}_{1}$.
Uninteresting $\mathcal{O}\left(N_{\text {Avogadro }} / 10^{23}\right)$ non-chiral open string spectra. Identification of D-branes under T-duality twists ... loss of chirality

## Part II: Bound-states of D-branes in L-R asymmetric vacua

## Type II superstring vacua with extended susy

[Ferrara, Kounnas; Dabholkar, Harvey]

$$
\begin{array}{lll}
\mathcal{N}=8 & \leftrightarrow & \mathcal{N}_{L}=4, \mathcal{N}_{R}=4 \\
\mathcal{N}=6 & \leftrightarrow & \mathcal{N}_{L}=2, \mathcal{N}_{R}=4 \\
\mathcal{N}=5 & \leftrightarrow & \mathcal{N}_{L}=1, \mathcal{N}_{R}=4 \\
\mathcal{N}=4 & \leftrightarrow & \mathcal{N}_{L}=2, \mathcal{N}_{R}=2 \quad \text { or } \quad \mathcal{N}_{L}=0, \mathcal{N}_{R}=4 \\
\mathcal{N}=3 & \leftrightarrow & \mathcal{N}_{L}=1, \mathcal{N}_{R}=2 \\
\mathcal{N}=2 & \leftrightarrow & \mathcal{N}_{L}=1, \mathcal{N}_{R}=1 \quad \text { or } \quad \mathcal{N}_{L}=0, \mathcal{N}_{R}=2
\end{array}
$$

Generically, L-R asymmetric and thus non-geometric but 'exact' vacuum configurations based on (rational) CFT's
When massless R-R states (eg graviphotons) survive there MUST be bound-states of D-branes they couple to
Some fraction of extended susy is preserved, BPS condition Use boundary states to determine open string excitations
$\mathcal{N}=6=2_{L}+4_{R}$ case
Spontaneous breaking $\mathcal{N}=8 \rightarrow \mathcal{N}=6$ via chiral $Z_{2}$ twist of the L-movers ('T-duality' on four internal directions, $T_{t}^{4}$ )

$$
X_{L}^{i} \rightarrow-X_{L}^{i} \quad, \quad \Psi_{L}^{i} \rightarrow-\Psi_{L}^{i} \quad, \quad i=6,7,8,9
$$

accompanied by an order two shift along untwisted $T_{s}^{2}$ Unbroken susy's satisfy

$$
\mathcal{Q}_{L}=\Gamma_{6789} \mathcal{Q}_{L}
$$

no conditions on $\mathcal{Q}_{R}$.
After dualizing all masseless 2 -forms into axions, the $30=2_{N S-N S}+12_{N S-N S}+16_{R-R}$ scalar moduli parameterize the space $\mathcal{M}_{\mathcal{N}=6}^{D=4}=S O^{*}(12) / U(6)$. The $16=8_{N S-N S}+8_{R-R}$ vectors together with their magnetic duals transform according to the 32 dimensional chiral spinor representation of $S O^{*}(12)$.

## $\mathcal{N}=6$ BPS branes, susy

Surviving $16_{R-R}=2_{(1 \mid 5)}+4_{(1 \mid 3)}+6_{(3 \mid 3)}+4_{(5 \mid 3)} R-R$ charges carried by D -brane bound-states invariant under twist and shift

$$
\begin{array}{rr}
q_{1}^{a}+\frac{1}{4!} \varepsilon_{i j k l} q_{5}^{a i j k l}, & q_{1}^{i}+\frac{1}{3!} \varepsilon_{j k \mid}^{i} q_{3}^{j k l}, \\
\left.q_{3}^{a i j}+\frac{1}{2!} \varepsilon^{i j} k \right\rvert\, q_{3}^{a k l} & , \quad q_{5}^{a b i j k}+\varepsilon^{i j k} / q_{3}^{a b l}
\end{array}
$$

Eg $1 / 3$ BPS state: D5 wrapped along twisted $T_{t}^{4} \times S_{s}^{1}$ and D1 along same $S_{s}^{1}$,

$$
\mathcal{Q}_{R}=\Gamma_{04} \Gamma_{6789} \mathcal{Q}_{L}=\Gamma_{04} \mathcal{Q}_{L}
$$

Different analysis for BPS states carrying NS-NS charges eg two massive gravitini and superpartners form a complex $1 / 2$ BPS multiplet
D-branes in T-folds [Brunner, Rajaraman, Rozali; Gutperle; MB, Morales, Pradisi; Gaberdiel,
Schafer-Nameki; Lawrence, Schulz, Wecht; Kawai, Sugawara]

## Other $\mathcal{N}=6$ cases

- $Z_{n}$ chiral projection acting on 4 super-coordinates as

$$
\left(Z^{1}, Z^{2}\right)_{L} \rightarrow\left(\omega Z^{1}, \omega^{-1} Z^{2}\right)_{L} \quad, \quad\left(\Psi^{1}, \Psi^{2}\right)_{L} \rightarrow\left(\omega \Psi^{1}, \omega^{-1} \Psi^{2}\right)_{L}
$$

with $\omega^{n}=1$. In order to avoid massless twisted states, combine with an order $n$ shift along the 'untwisted' directions $\left(Z_{L}^{3} ; Z_{R}^{i}\right)$

- maximal torus of $S U(3)^{3}$ with chiral $Z_{3}$ projection and no shift. $\mathcal{N}=5$ supergravity in untwisted sector. Twisted sector produces the extra massless gravitino multiplet to complete the spectrum of $\mathcal{N}=6$ supergravity [Dabholkar, Harvery]


## Other extended susy cases with $L \neq R$

- $\mathcal{N}=5=1_{L}+4_{R}$, unique massless spectrum, non-geometric, uncorrected LEEA (as for $\mathcal{N}=6,8$ )
- $\mathcal{N}=4=2_{L}+2_{R}$ uncorrected LEEA, (non)geometric, $S L(2) \times S O\left(6, N_{v}\right)$ symmetry
- $\mathcal{N}=3=1_{L}+2_{R}$ uncorrected LEEA, non-geometric / fuxes, $U\left(3, N_{v}\right)$ symmetry
- $\mathcal{N}=2=1_{L}+1_{R}$, (non) geometric, quantum corrections absent in special cases $(\chi=0$, eg FHSV, octonionic magic)
- $\mathcal{N}=4=0_{L}+1_{R}, \mathcal{N}=4=0_{L}+2_{R}, \mathcal{N}=1=0_{L}+1_{R} \mathrm{NO}$ massless R-R graviphotons, NO BPS D-branes
Focus on $\mathcal{N}=5,3$

$$
\mathcal{N}=5=1_{L}+4_{R} \text { case }
$$

Simple(st) realization [Ferara, Kounnas] $Z_{2}^{L} \times Z_{2}^{L}$ which acts by T-duality along $T_{6789}^{4}$ and $T_{4589}^{4}$ combined with order two shifts $1 / 5$ BPS bound states of D-branes carrying $8_{R-R}=6_{(1533)}+2_{(3333)} R-R$ charges (invariant orbits)
where $i_{l}, j_{l}, k_{l}, l_{l}$ run over the four directions orthogonal to $T_{l}^{2}$ while $K^{\prime}, L^{\prime}$ and $K^{\prime \prime}, L^{\prime \prime}$ run over the two sets of two directions orthogonal to $T_{l}^{2}$ and

$$
q_{(3333)}^{I_{1} I_{2} I_{3}}=q_{3}^{I_{1} I_{2} I_{3}}+\frac{1}{2!} \varepsilon^{l_{2} I_{3}} J_{2} J_{3} q_{3}^{I_{1} J_{2} J_{3}}+\frac{1}{2!} \varepsilon^{I_{3} I_{1}} J_{3} J_{1} q_{3}^{J 1 I_{2} J_{3}}+\frac{1}{2!} \varepsilon^{I_{1} I_{2}} J_{1} J_{2} q_{3}^{J_{1} J_{2} I_{3}}
$$

$$
\mathcal{N}=3=1_{L}+2_{R} \text { case }
$$

The simplest $\mathcal{N}=3$ model with 3 matter vector-plets. Two steps

- 'geometric' $Z_{2}$ freely acting orbifold (locally equivalent to $K 3 \times T^{2}$ ). The $Z_{2}$ action combines a twist breaking $\mathcal{N}=8=4_{L}+4_{R}$ to $\mathcal{N}=4=2_{L}+2_{R}$ and a shift preventing massless twisted states
- non geometric chiral (say Left-) projection combined with a shift along the orthogonal directions $a=4,5$
Surviving NS-NS charges: $p_{R}^{a}$ and their magnetic duals $\hat{P}_{R}^{a}$. Surviving R-R charges: T-duality invariant combinations

$$
q_{1}^{a}+\frac{1}{3!} \varepsilon_{b i j}^{a} q_{3}^{b i j} \quad, \quad q_{3}^{a i j}+\frac{1}{3!} \varepsilon_{b k l}^{a} q_{5}^{b i j k l}
$$

One can consider $1 / 3$ BPS states.
Massive gravitino in $\mathcal{N}=4 \rightarrow \mathcal{N}=3$ long multiplet.
No $1 / 2$ BPS states

## Boundary states for L-R asymmetric branes

[Abouelsaood, Callan, Lovelace, Nappi, Yost; Billò, Di Vecchia, Frau, Lerda, Pesando].
Bosonic coordinates

$$
\left|B_{a}\right\rangle^{(X)}=\sqrt{\operatorname{det}\left(\mathcal{G}_{a}+\mathcal{F}_{a}\right)} \exp \left(-\sum_{n>0} a_{-n}^{i} R_{i j}\left(F_{a}\right) \tilde{a}_{-n}^{j}\right)\left|0_{a}\right\rangle
$$

where $R_{a}=\left(1-F_{a}\right) /\left(1+F_{a}\right)$ and $\left|0_{a}\right\rangle \leftrightarrow p_{L}=-R_{a} p_{R}$
NS-NS sector (no fermionic zero-modes)

$$
\left|B_{a}, \pm\right\rangle_{N S-N S}^{(\psi)}=\exp \left( \pm i \sum_{n \geq 1 / 2} \psi_{-n}^{i} R_{i j}\left(F_{a}\right) \tilde{\psi}_{-n}^{j}\right)| \pm\rangle
$$

R-R sector

$$
\begin{gathered}
\left|B_{a}, \pm\right\rangle_{R-R}^{(\psi)}=\frac{1}{\sqrt{\operatorname{det}\left(\mathcal{G}_{a}+\mathcal{F}_{a}\right)}} \exp \left(i \pm \sum_{n>0} \psi_{-n}^{i} R_{i j}\left(F_{a}\right) \tilde{\psi}_{-n}^{j}\right) \mathcal{U}_{A \tilde{B}}^{ \pm}\left(F_{a}\right)|A, \tilde{B}\rangle \\
\mathcal{U}_{A \tilde{B}}^{ \pm}\left(F_{a}\right)=\left[\operatorname{AExp}\left(-F_{i j}^{a} \Gamma^{i j} / 2\right) C \Gamma_{11} \frac{1 \pm i \Gamma_{11}}{1 \pm i}\right]_{A \tilde{B}}
\end{gathered}
$$

## Partition functions and tree channel

Magnetized / Intersecting D-branes in L-R symmetric orbifolds
[Angelantonj, Sagnotti; Blumenhagen, Cvetic, Langacker, Shiu; Blumenhagen, Körs, Lüst, Stieberger]
Generalize to $Z_{N_{L}}^{L} \times Z_{N_{R}}^{R}$ action, invariant boundary states would then be of the form

$$
\begin{aligned}
|B, F\rangle_{g} & =\frac{1}{\sqrt{N_{L} N_{R}}}\left(1+g_{L}+g_{R}+\ldots .+g_{L}^{N_{L}-1} g_{R}^{N_{R}-1}\right)|B, F\rangle= \\
& =\frac{1}{\sqrt{N_{L} N_{R}}} \sum_{l, r}\left|B, F_{(I, r)}\right\rangle
\end{aligned}
$$

where the 'induced' magnetic field $F_{(1, r)}$ is determined by the condition

$$
\begin{gathered}
R\left(F_{(I, r)}\right)=R\left(g_{L}^{\prime}\right) R(F) R^{t}\left(g_{R}^{r}\right) \\
\mathcal{A}_{g, h}=\Lambda(g, h) \mathcal{I}(g, h) \sum_{\alpha} c_{\alpha}^{G s o} \frac{\vartheta_{\alpha}(0)}{\eta^{3}} \prod_{l} \frac{\vartheta_{\alpha}\left(\epsilon_{I}(g, h) \tau\right)}{\vartheta_{1}(\epsilon(g, h) \tau)}
\end{gathered}
$$

## Example: $\mathcal{N}=5$ model on $T^{6} / Z_{3}^{L}$ torus of $S U(3)^{3}$

Prior to twists and shifts, 27 boundary states

$$
\mathcal{A}_{\vec{r}, \vec{s}}=N_{\vec{r}, \vec{s}}^{\vec{t}} \mathcal{X}_{\vec{t}}
$$

where $\mathcal{X}_{\vec{t}}=\left(V_{8}-S_{8}\right) \chi_{t_{1}} \chi_{t_{2}} \chi_{t_{3}}$ correspond to branes with magnetic quantum number $(n, m)=(1,0),(-1,1),(0,-1)$
After twist and shift: branes rotated and displaced wrt one another

$$
\mathcal{A}_{Z_{3}^{\llcorner\neq R}}=\frac{1}{6} \sum_{a, b \in Z_{3}} \Lambda_{(a, b)} \mathcal{I}_{(a, b)} \sum_{\alpha} c_{\alpha}^{G S O} \frac{\vartheta_{\alpha}(0)}{\eta^{3}} \prod_{l} \frac{\vartheta_{\alpha}(a \tau+b)}{\vartheta_{1}(a \tau+b)}
$$

Both 'untwisted' and 'twisted' strings are present [MB, Morales, Pradisi; Blumehagen, Gorlich, Kors, Lüst; ...], yet non chiral spectra

## Outlook

Twists and shifts can conveniently combine with other mechanisms, e.g. open and closed string fluxes, non-anomalous $U(1)$ 's, instanton effects, ... of moduli stabilization.
Explicit computations are feasible. Model with only $1+1$ twisted moduli.. some tension with chirality $(\chi=0)$
D-branes in L-R asymmetric vacua, very promising ... yet relation with (non) geometric fluxes [Lawrence, Schulz, Wecht], [Hull, ...], [Berman, ...], [Villadoro, Zwirner], ... to be understood and interacting CFT's (WZW, Gepner or alike) to be worked out [Kawai, Sugawara]

## Announcements

- Strings '09

Rome, 22-26 June 2009
Angelicum - Pontificia Università S. Tommaso http://people.roma2.infn.it/ strings2009/

- New Perspectives in String Theory GGI, Arcetri (Florence), 6 April - 19 June 2009 http://ggi-
www.fi.infn.it/index.php?p=events.inc\&id=25

