Annual Presentation on YITP Research Activities

Apr. 2006 – Mar. 2007

湯川・朝永
生誕100年

Particle Theory Group

Hiroyuki ABE, Tetsuji KIMURA, and Shin SASAKI

March 9th, 2007

Introduction

– overview –

String Theory

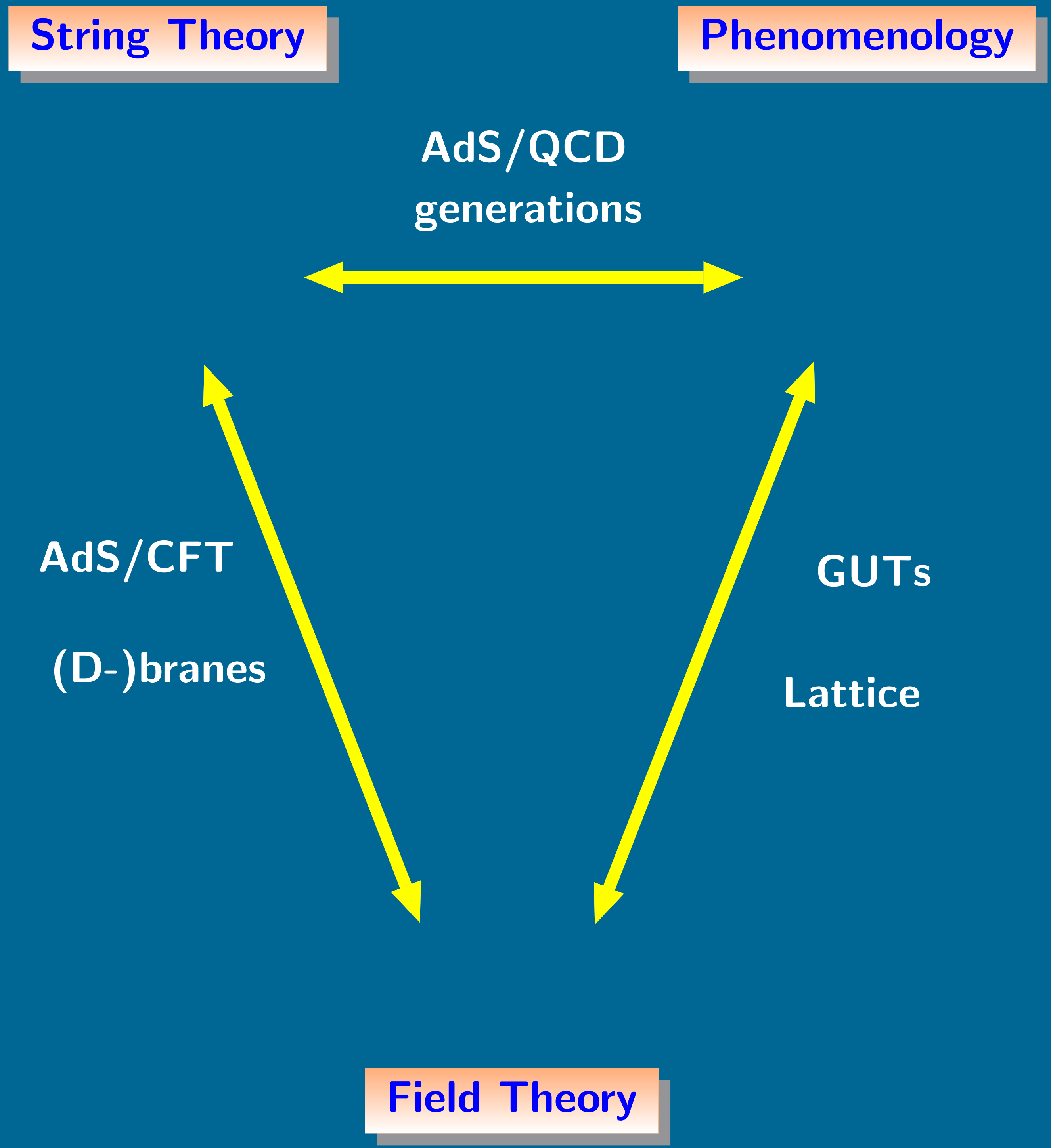
- formulation of the fundamental model
- application to mathematics

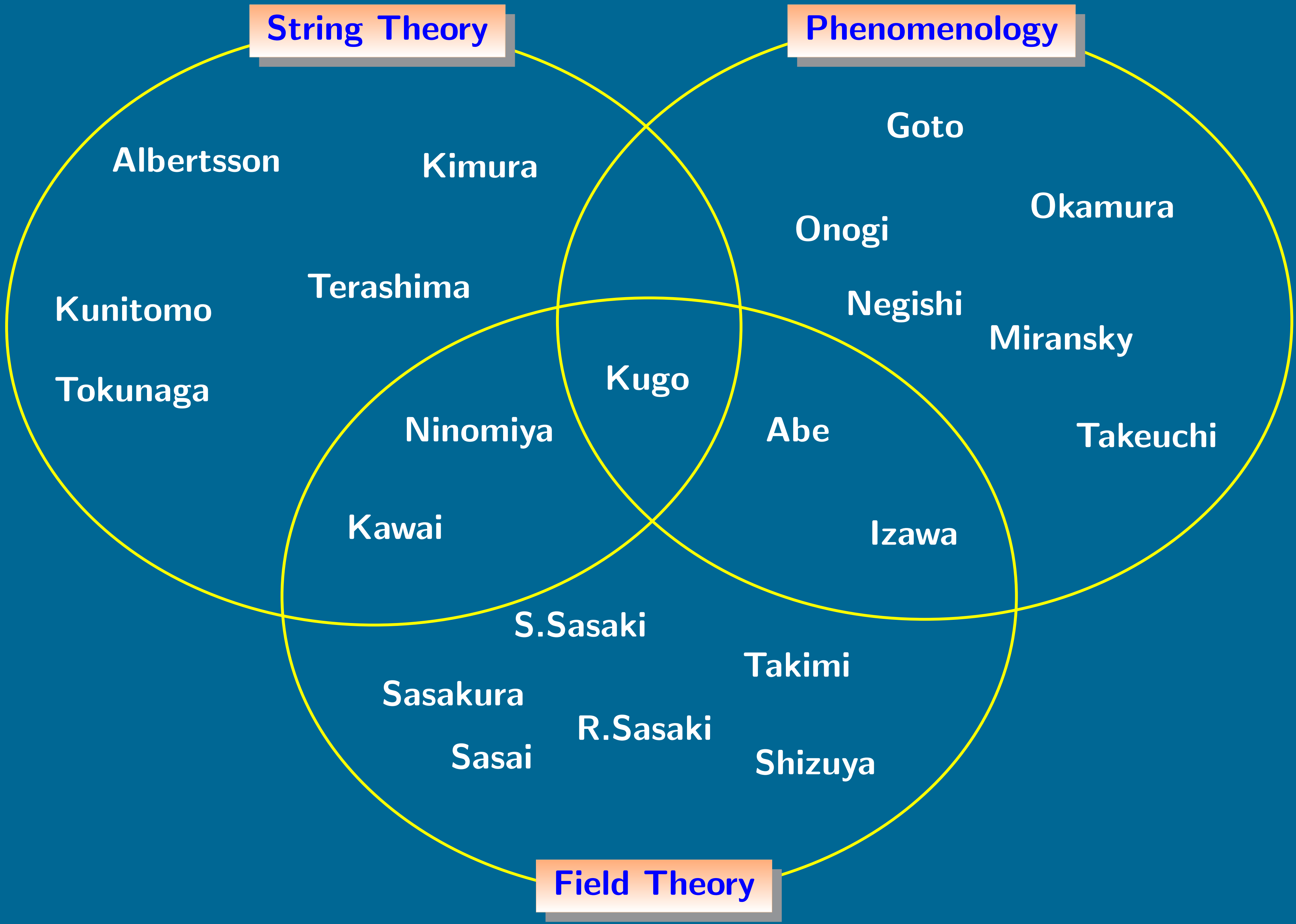
Phenomenology

- deep insight of particle interactions
- support/explain the experimental data from RHIC, T2K, LHC, ILC..

- non-perturbative analysis
- connection to matter physics

Field Theory


String Theory
Phenomenology
AdS/QCD
generations
AdS/CFT
(D-)branes
GUTs
Lattice
Field Theory


String Theory
Phenomenology
Field Theory
Albertsson
Kimura
Terashima
Kunitomo
Tokunaga
Goto
Okamura
Onogi
Negishi
Miransky
Takeuchi
Kugo
Ninomiya
Kawai
Abe
Izawa
S.Sasaki
Takimi
Sasakura
R.Sasaki
Sasai
Shizuya

STRING THEORY

MEMBERS who mainly study String Theory

- **Taichiro Kugo**
- **Hiroshi Kunitomo**
- **Seiji Terashima** — new member
- **Shinsuke Kawai**
- **Cecilia Albertsson**
- **Tetsuji Kimura** — new member
- **Tatsuya Tokunaga**

Taichiro Kugo

Superconformal tensor calculus in 5-dim.

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Motivation

To investigate various problems

Seriously in the BRANE WORLD scenario,

we need

$\boxed{\text{Off-shell supergravity in 5D}}$

or superconformal tensor calculus

Why 5D ?

→ Simplest : a single extra dim.

→ M-theory compactified on CY_3
(11-D SUGRA) S^1/Z_2 Hořava-Witten

→ 5D Sugra on S^1/Z_2
Lukas et. al.

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Conclusion

1. Superconformal tensor calculus in 5D bulk

   - Weyl / hyper / vector / tensor multiplets
   - Invariant action formula
   - General action (一般系の具体的形)

2. 4D superconformal multiplets induced on the boundary S^1/Z_2

   - Coupling of 5D bulk fields and fields living on the boundary

3. Unsolved problem

   How do 5D bulk fields couple to fields living on D-branes ?

Hiroshi Kunitomo

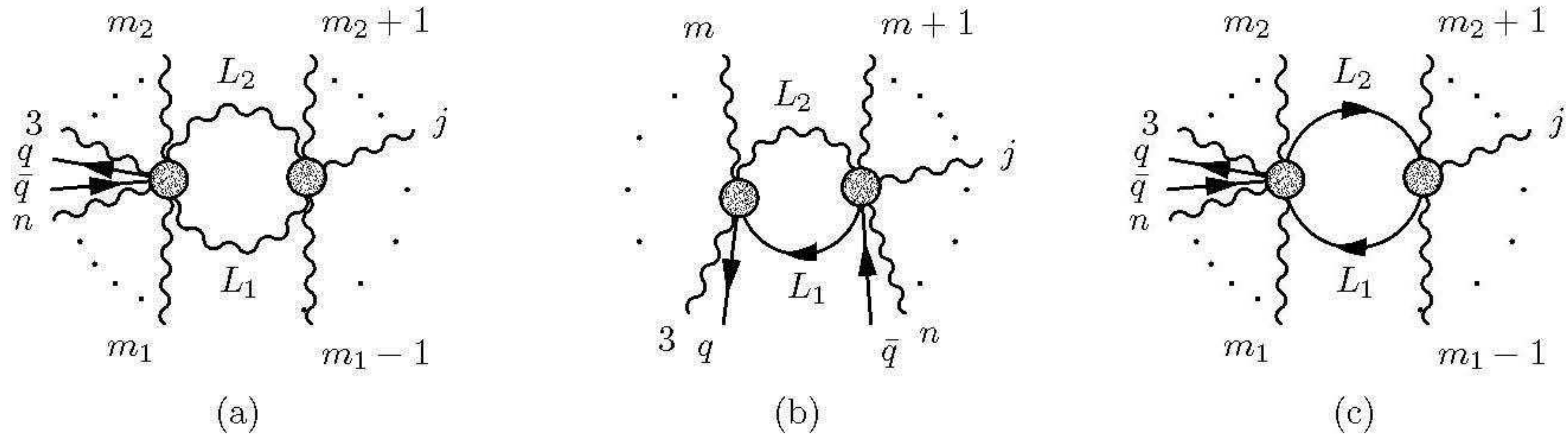
"One-loop amplitudes in supersymmetric QCD from MHV vertices"

- ▶ The CSW rules using MHV vertices for $N = 1$ SQCD is given.
- ▶ All the one-loop MHV amplitudes in $\mathcal{N} = 1$ SQCD are given.

  - ◦ quark $+$ anti-quark $+$ gluons
  - ◦ (quark $+$ anti-quark)^2 $+$ gluons

"Lower-dimensional superstrings in the double-spinor formalism"

- ▶ Lower-dimensional superstring is investigated in the double-spinor formalism.



One-loop diagrams for quark + $\overline{\text{quark}}$ + gluons MHV amplitudes.

KEY: Twistor Space

$$\boldsymbol{P_{\alpha\dot{\alpha}} = (\sigma_\mu)_{\alpha\dot{\alpha}} P^\mu \equiv \lambda_\alpha \bar{\lambda}_{\dot{\alpha}}}$$

spinor space$(\boldsymbol{\lambda_\alpha}, \boldsymbol{\bar{\lambda}_{\dot{\alpha}}})$ $\longrightarrow$ twistor space$(\boldsymbol{\lambda_\alpha}, \boldsymbol{\mu^{\dot{\alpha}}})$

via Fourier transformation

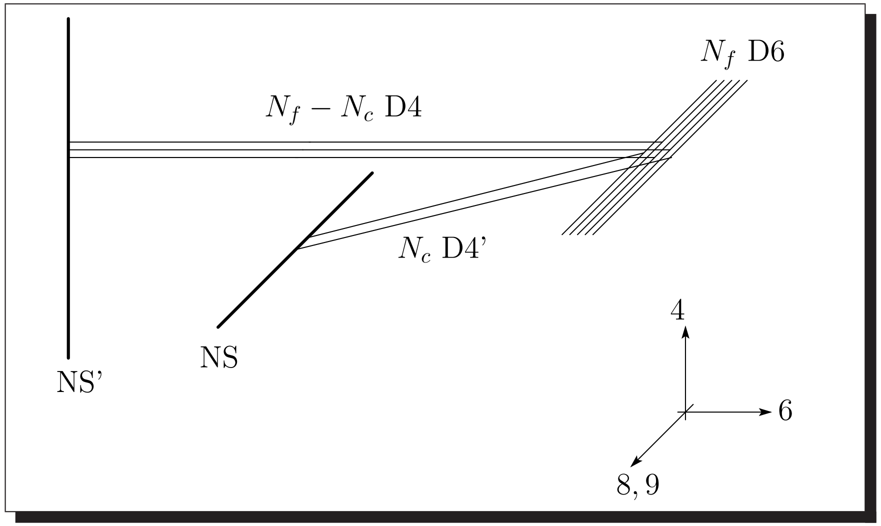
Seiji Terashima

Seiji Terashima has worked on 2 topics while at YITP.
First topic is solitons in the meta-stable vacua
and the other topic is the supertube.
Below the former work was reviewed

Recently SUSY-breaking meta-stable vacua of the SUSY QCD was found. These vacua provide simple models of the phenomenological SUSY breaking sector. The solitons, like strings and monopoles, in the theory is very important in the light of cosmology, especially, the experimental search of the cosmic string.

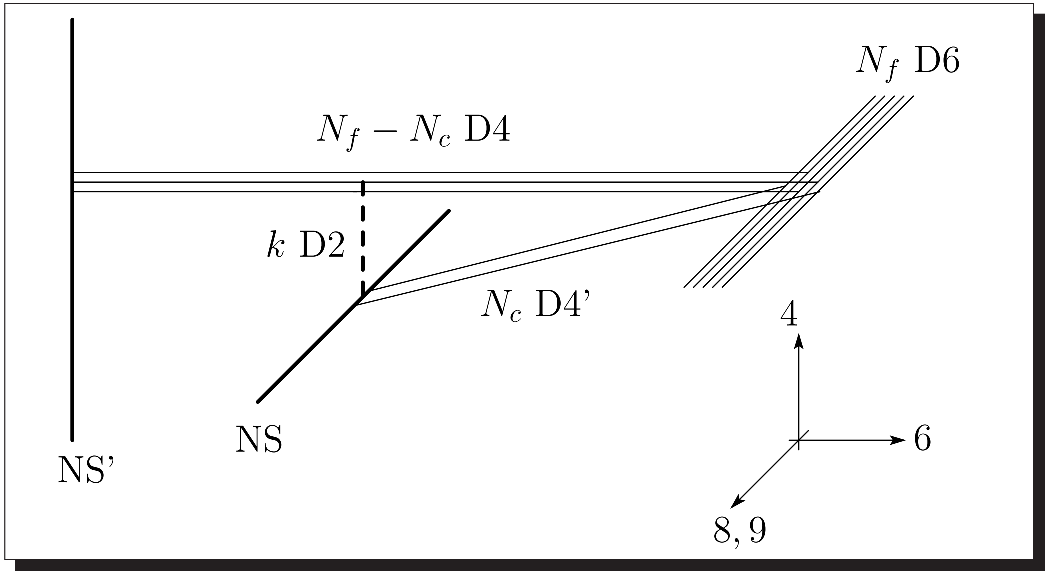
Thus we examine the possible existence of the soliton. We show there is no nontrivial soliton, however, when U(1)_B symmetry present in the theory is gauged, we find non-BPS vortex strings whose existence and properties are predicted from D-brane configurations in string theory.

M.Eto, K.Hashimoto and S.Terashima,
``Solitons in supersymmetry breaking meta-stable vacua,''
hep-th/0610042, to appear in JHEP.



Meta-stable vacua

in SUSY QCD realized in D-branes



NS	1	2	3	–	–	–	–	8	9
NS'	1	2	3	4	5	–	–	–	–
D6	1	2	3	–	–	–	7	8	9
D4	1	2	3	–	–	6	–	–	–
D4'	1	2	3	(4)	–	(6)	–	–	–
D2	–	–	3	4	–	–	–	–	–

Vortex can be visualized as D2-brane

Shinsuke Kawai

Conformal field theory of T-folds and Mirror-folds in superstring compactifications -- work in collaboration with Y. Sugawara (Tokyo)

Discrete symmetries in string theory: S, T, U-duality, mirror symmetry, etc.

$\Rightarrow$ May be included in boundary conditions for constructing internal CFT of string theory.

Particular examples of interest: T-duality in tori, Mirror symmetry of CY.

Supergravity analysis: Hull, Dabholkar, ...

We studied these models using exact CFT (orbifold) solutions.

New features:

Novel constraints from locality of operators

Bulk and fractional D-branes

...

To appear: S. Kawai, Y. Sugawara, hep-th/0703XXX

Cecilia Albertsson

- **Poisson-Lie T-duality: A generalisation of traditional T-duality, requiring no isometry.**
- **Poisson-Lie T-plurality: A generalisation of P-L T-duality, allowing more freedom in choice of target space.**
- **Given some restrictions on the background, conformal boundary conditions of the two-dimensional nonlinear sigma model are P-L T-dual to conformal boundary conditions.**
- **Derived the explicit duality and plurality transformations for the gluing matrix encoding the boundary conditions.**
- **Applied P-L T-duality to specific two- and three-dimensional examples, finding the sets of dual D-branes in each case.**

C. Albertsson and R. Reid-Edwards, JHEP 03 (2007) 004, hep-th/0606024

C. Albertsson, L. Hlavaty, L. Snobl and M. Turek, in preparation

Poisson-Lie T-duality

$$\begin{tikzcd} & \mathrm{D} \arrow[dl] \arrow[dr] & \\ G & & \widetilde{G} \\ S[X] & & \widetilde{S}[\widetilde{X}] \end{tikzcd}$$

$$\partial_- X^\mu = R^\mu{}_\nu \partial_+ X^\nu \quad \Longleftarrow \ \textbf{duality map} \ \Longrightarrow \quad \partial_- \widetilde{X}^\mu = \widetilde{R}^\mu{}_\nu \partial_+ \widetilde{X}^\nu$$

$$\widetilde{R} = f_d(R)$$

Poisson-Lie T-plurality

$$\begin{tikzcd} & \mathrm{D} \arrow[dl] \arrow[dr] & \\ (G, \widetilde{G}) & & (\widehat{G}, \bar{G}) \\ S[X] \arrow[u] & & \widehat{S}[\widehat{X}] \arrow[u] \end{tikzcd}$$

$$\partial_- X^\mu = R^\mu{}_\nu \partial_+ X^\nu \quad \Longleftarrow \ \textbf{plurality map} \ \Longrightarrow \quad \partial_- \widehat{X}^\mu = \widehat{R}^\mu{}_\nu \partial_+ \widehat{X}^\nu$$

$$\widehat{R} = f_p(R)$$

Geometric Engineering of Chern-Simons Gravity

H.Fuji (Hokkaido Univ.) and T.Tokunaga (Yukawa Inst.) hep-th/0703xxx

We exactly derived the dimer partition functions from topological string.

Dimer partition functions are mathematically defined partition functions which count the ways to lay dominos (=dimers) on a space thoroughly.

Regularized topological string amplitudes with one D-brane

large N limit $\downarrow$

Dimer partition functions

Physically, this work was motivated by the recent developments of quiver gauge theory, string theory on AdS5xSasaki-Einstein manifolds and toward a new AdS5/CY3 correspondence.

Tetsuji Kimura

- **No-go theorem on flux compactification in HETEROTIC STRING**

  Flux compactification w/ $\mathrm{d}H = 0$ on a smooth manifold is forbidden.

  Smooth compactifications with $H \neq 0$ and $\mathrm{d}H \neq 0$ are possible.

  (New gauge symmetry breaking scenarios also appear.)

- **Atiyah-Singer Index theorem in HETEROTIC STRING**

  Flux also affects topological invariants on a geometry.

  $\longrightarrow$ closely related to $\#$ of moduli, and of generations in 4-dim. physics!

P.Yi and T.Kimura, JHEP 07 (2006) 030 (hep-th/0605247) at KIAS

P.Yi and T.Kimura, in progress

Atiyah-Singer Index Theorem on conformally balanced manifolds

Necessary to analyze it *in heterotic string compactification* *with NS-fluxes*:

$\mathcal{N}=1$ SUSY without fluxes Calabi-Yau	$\rightarrow$	$\mathcal{N}=1$ SUSY with fluxes Conformally balanced

Dirac operator is modified:

$$D_m(\omega - \tfrac{1}{3}H) \;=\; \partial_m + \frac{1}{4}\Big(\omega_{mab} - \frac{1}{3}H_{mab}\Big)\Gamma^{ab}$$

$$\not{D}^2 \;=\; \frac{1}{\sqrt{g}} D_m(\omega - H) g^{mn}\sqrt{g} D_n(\omega - H) - \frac{1}{4}\left(R(\omega) - \frac{1}{3}H_{mnp}H^{mnp} + \frac{1}{12}(\mathrm{d}H)_{mnpq}\Gamma^{mnpq}\right)$$

Chiral anomaly: $\mathcal{A} = \lim_{\beta\to 0} \mathrm{Tr}\{\Gamma_{(5)} \exp(\beta \not{D}^2)\}$

(ex.) the 1st Pontrjagin class is modified! (even in $\mathrm{d}H = 0$ case):

$$\mathcal{A}(\mathcal{M}_4) = \frac{1}{192\pi^2} \int_{\mathcal{M}_4} \mathrm{tr}\Big\{ R_2(\omega) \wedge R_2(\omega) \Big\} - \frac{1}{8\pi^2} \int_{\mathcal{M}_4} F_2(\widetilde{H}) \wedge F_2(\widetilde{H}) + \int_{\mathcal{M}_4} \Big(\text{total derivative terms} \Big)$$

with $\quad H_{abc} \equiv -\sqrt{\frac{3}{2}}\, \mathcal{E}_{abcd}\, \widetilde{H}^d \,, \qquad F_{ab} \equiv \partial_a \widetilde{H}_b - \partial_b \widetilde{H}_a \qquad$ (in 4-dim.)

Significance of the Index Theorem in Physics

- $\#$ of massless fields, in particular, $\#$ of generations
- gauge symmetry breaking from $E_8 \times E_8$