# 場の量子論、弦理論と数学の相互作用

- 立川裕二(たちかわゆうじ)
- 去年の四月から働いています。学生は修士一年が一人いるだけです。

- 諸井研/濱口研 (素粒子現象論)
- 松尾研/立川研 (弦理論)
- 日々の活動は一緒にやってます。
  セミナー、文献紹介、雑談等

- IPMU の素粒子論とは合同で院試をしています。
- 僕は二週に一回ぐらい IPMU に行っています。もっと頻繁に行きたい...

- 昨年度にこの研究室紹介でいろいろ質問されたときの典型的な問答集を僕のホームページに貼ってあるのでどうぞ:

  http://member.ipmu.jp/yuji.tachikawa/

- こんなのもやっています:

  http://twitter.com/yujitach

Yuji Tachikawa

member.ipmu.jp/yuji.tachikawa/

admin News phys shops conf junk seminar 原発

# Yuji Tachikawa

## Interests

- String or field theories with eight supercharges and/or deformations thereof; geometric structures associated to such theories

## Works

- Please refer to INSPIRE database.
- Articles **not** on the arXiv.
- Transparencies of my old talks.
- Comments on some of my papers (in Japanese)

## CV

| | | | | | |
|---|---|---|---|---|---|
| Apr, 2012 | – | | Associate Professor, | Particle Theory Group, | Dept. of Physics, Univ. of Tokyo. |
| Nov, 2010 | – | Mar, 2012 | Assistant Professor, | IPMU, | University of Tokyo |
| Oct, 2006 | – | Aug, 2011 | Post-doctoral fellow, | School of Natural Sciences, | Institute for Advanced Studies |
| | – | Sep, 2006 | Graduate Student, | Particle Theory Group, | Dept. of Physics, Univ. of Tokyo. |

## 講義の連絡等


Yuji Tachikawa
member.ipmu.jp/yuji.tachikawa/
admin
News
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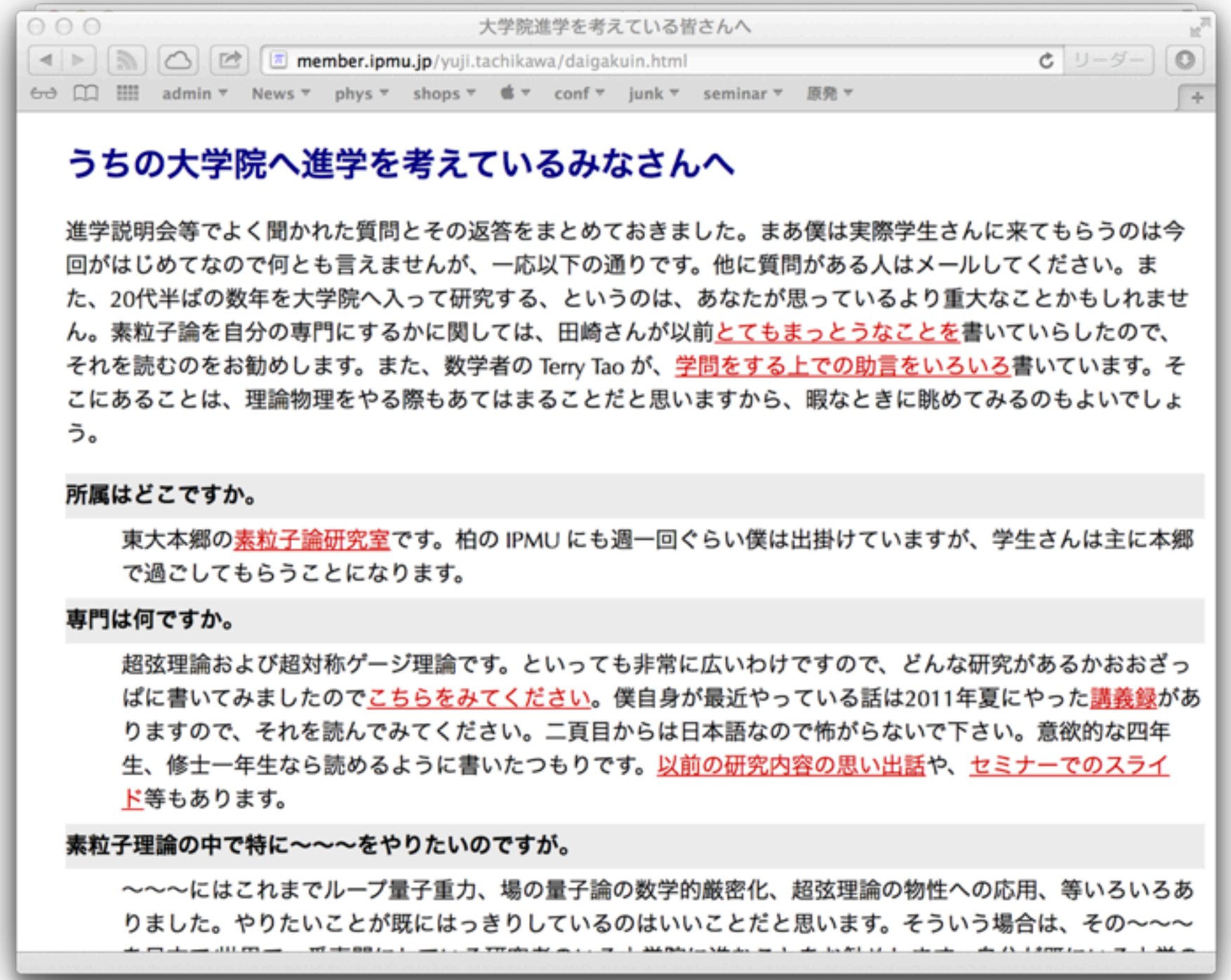
conf
junk
seminar
CV
Apr, 2012 – Associate Professor, Particle Theory Group, Dept. of Physics, Univ. of Tokyo.
Nov, 2010 – Mar, 2012 Assistant Professor, IPMU, University of Tokyo
Oct, 2006 – Aug, 2011 Post-doctoral fellow, School of Natural Sciences, Institute for Advanced Studies
– Sep, 2006 Graduate Student, Particle Theory Group, Dept. of Physics, Univ. of Tokyo.
講義の連絡等
講義一覧
うちの研究室へ進学を考えている皆さんへ
For those who want to join our group as students
Miscellany
I made unofficial pages hosting slides presented at past Strings conferences here.
I made a small program spires.app to manage PDF files downloaded from arxiv.org.
I wrote an instruction of how you can post a Chinese/Japanese/Korean TeX file to the arxiv.
Here is the slideshow of the photos I have taken.
I'm keeping a diary in Japanese.
email: yuji.tachikawa_at_****.**




# うちの大学院へ進学を考えているみなさんへ

進学説明会等でよく聞かれた質問とその返答をまとめておきました。まあ僕は実際学生さんに来てもらうのは今回がはじめてなので何とも言えませんが、一応以下の通りです。他に質問がある人はメールしてください。また、20代半ばの数年を大学院へ入って研究する、というのは、あなたが思っているより重大なことかもしれません。素粒子論を自分の専門にするかに関しては、田崎さんが以前とてもまっとうなことを書いていらしたので、それを読むのをお勧めします。また、数学者の Terry Tao が、学問をする上での助言をいろいろ書いています。そこにあることは、理論物理をやる際もあてはまることだと思いますから、暇なときに眺めてみるのもよいでしょう。

**所属はどこですか。**

東大本郷の素粒子論研究室です。柏の IPMU にも週一回ぐらい僕は出掛けていますが、学生さんは主に本郷で過ごしてもらうことになります。

**専門は何ですか。**

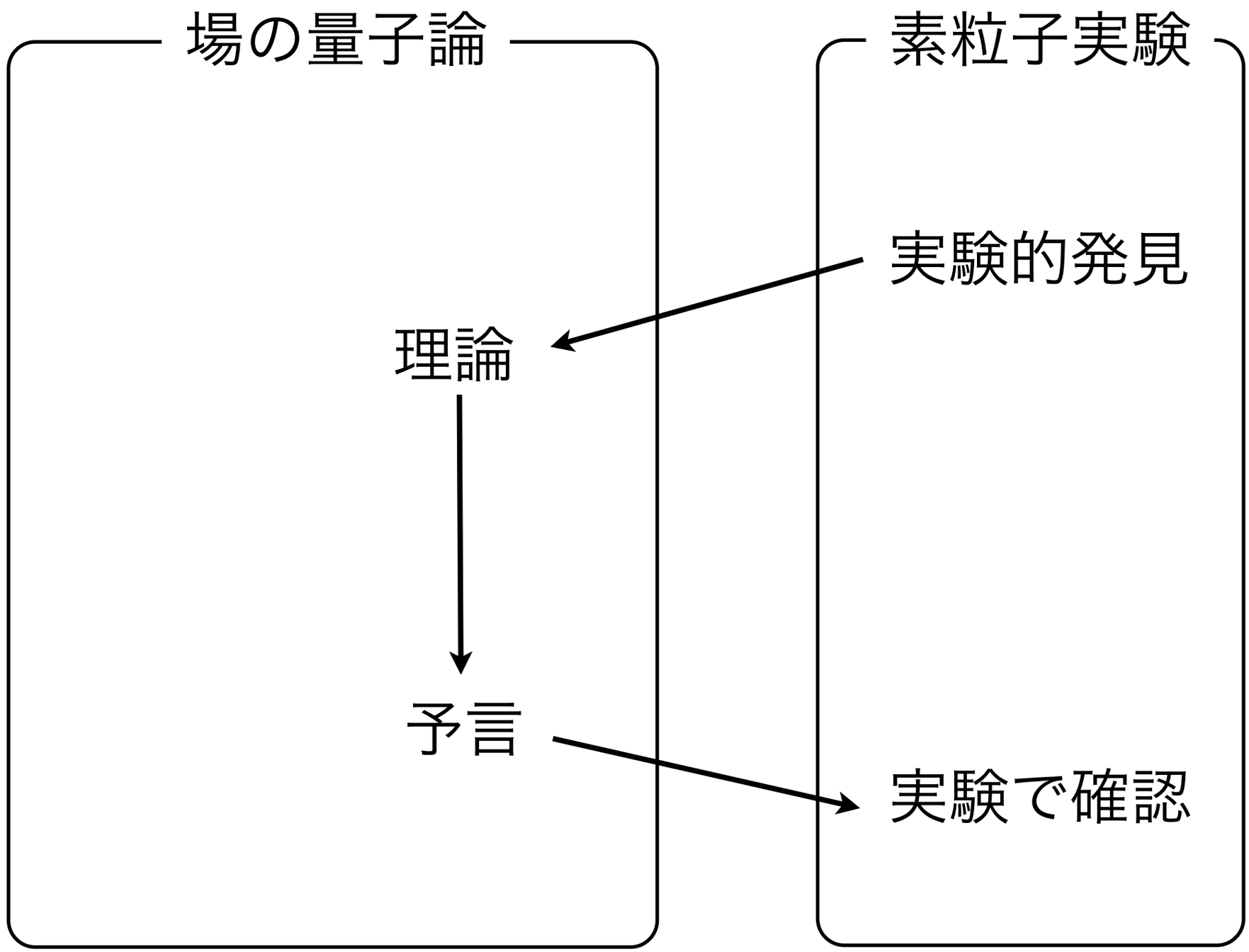
超弦理論および超対称ゲージ理論です。といっても非常に広いわけですので、どんな研究があるかおおざっぱに書いてみましたのでこちらをみてください。僕自身が最近やっている話は2011年夏にやった講義録がありますので、それを読んでみてください。二頁目からは日本語なので怖がらないで下さい。意欲的な四年生、修士一年生なら読めるように書いたつもりです。以前の研究内容の思い出話や、セミナーでのスライド等もあります。

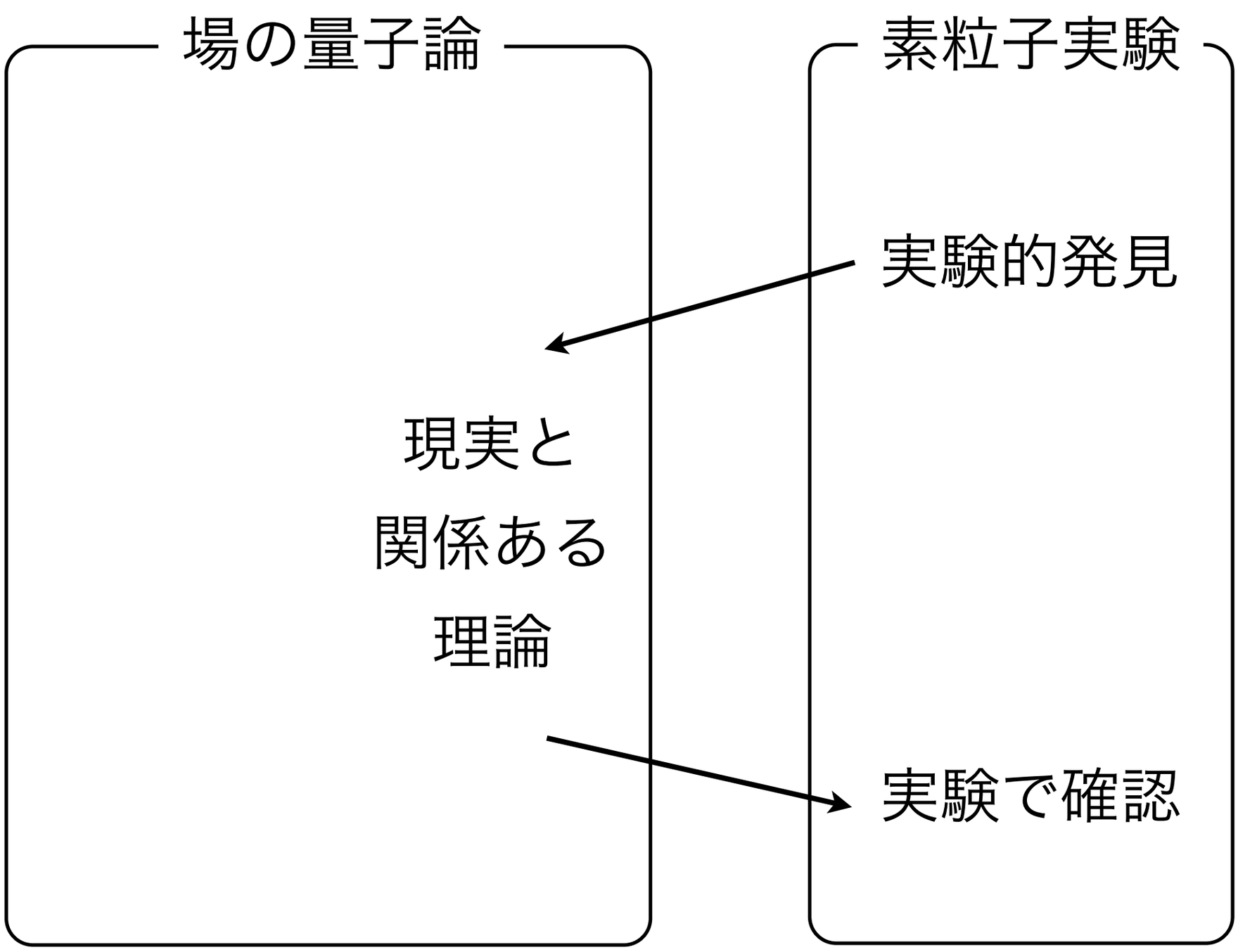
**素粒子理論の中で特に〜〜〜をやりたいのですが。**

〜〜〜にはこれまでループ量子重力、場の量子論の数学的厳密化、超弦理論の物性への応用、等いろいろありました。やりたいことが既にはっきりしているのはいいことだと思います。そういう場合は、その〜〜〜

- 20代の数年間を費やすのは案外重大な決断。
- 一度のみの人生だから、折角だから一番やりたいことをやってください。

- 数学と物理の中間のようなことをやっています。
- 場の量子論および超弦理論の性質を調べている。
- 場の量子論と超弦理論はそんなに本質的には異ならない。


場の量子論
素粒子実験
実験的発見
理論
予言
実験で確認


場の量子論
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現実と
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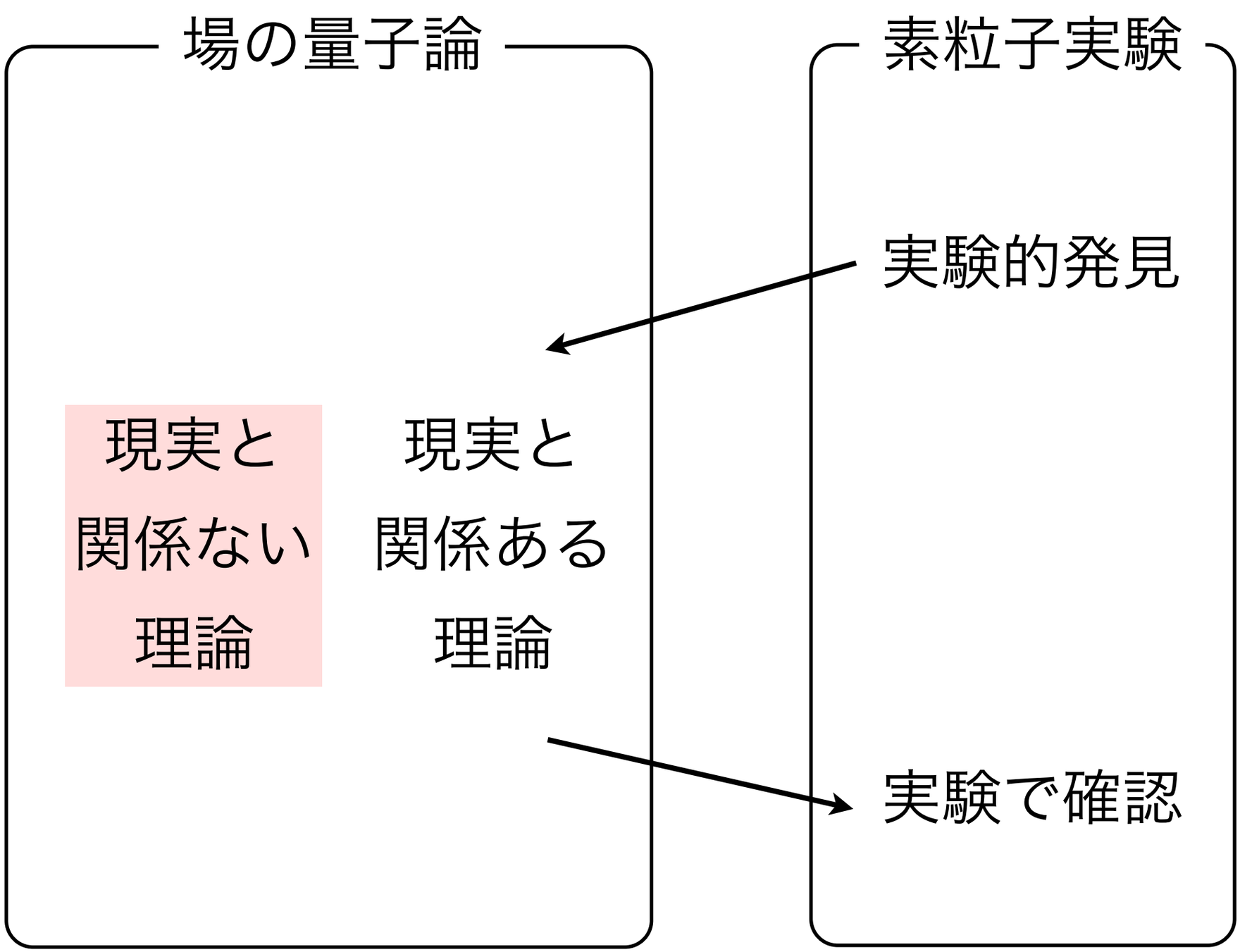
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厳密数学

場の量子論

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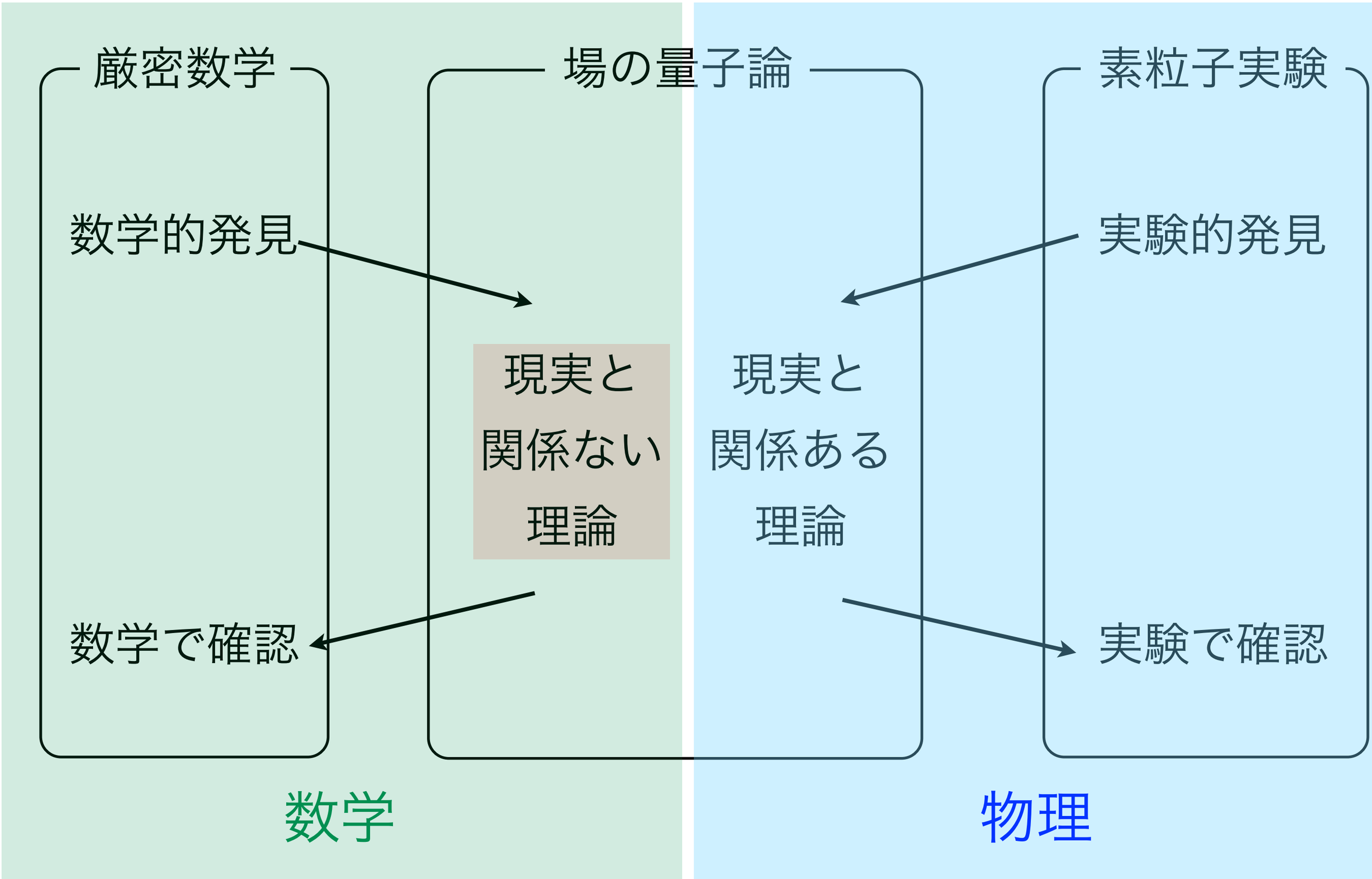
現実と関係ある理論

数学で確認

実験で確認

僕はココ


厳密数学
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理論
現実と
関係ある
理論
数学で確認
実験で確認
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物理

物理の人に聞くと...

厳密数学

数学的発見

数学で確認

場の量子論

現実と関係ない理論

現実と関係ある理論

素粒子実験

実験的発見

実験で確認

数学

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数学的発見

数学で確認

場の量子論

現実と関係ない理論

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僕はココ

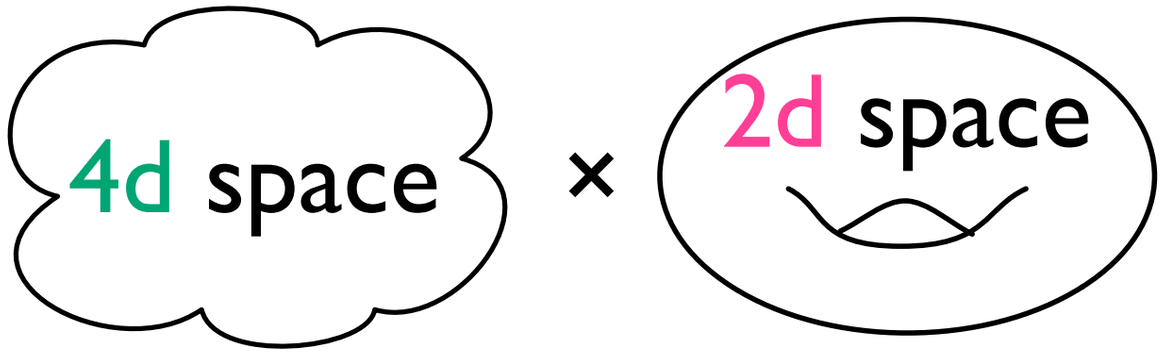
- この世は四次元だが、数理的にはとても面白い六次元の理論がある。

*N*=(2,0) supersymmetric 6d theory

という変な名前だが、

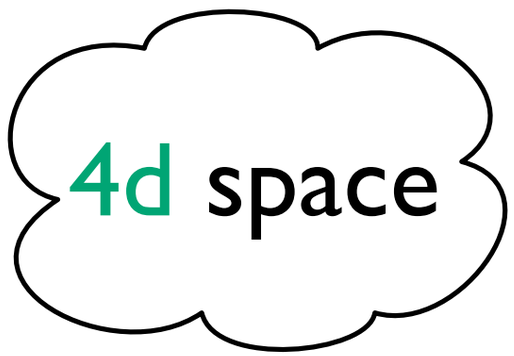
世界中で沢山の人が研究している。

6次元理論を




で考える

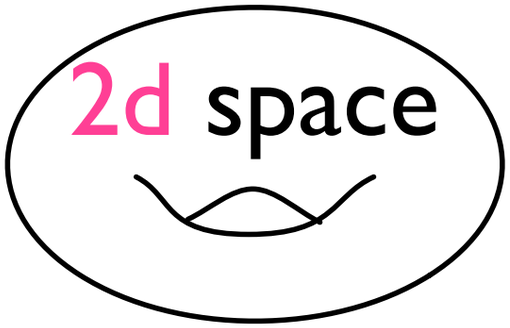
4次元理論を



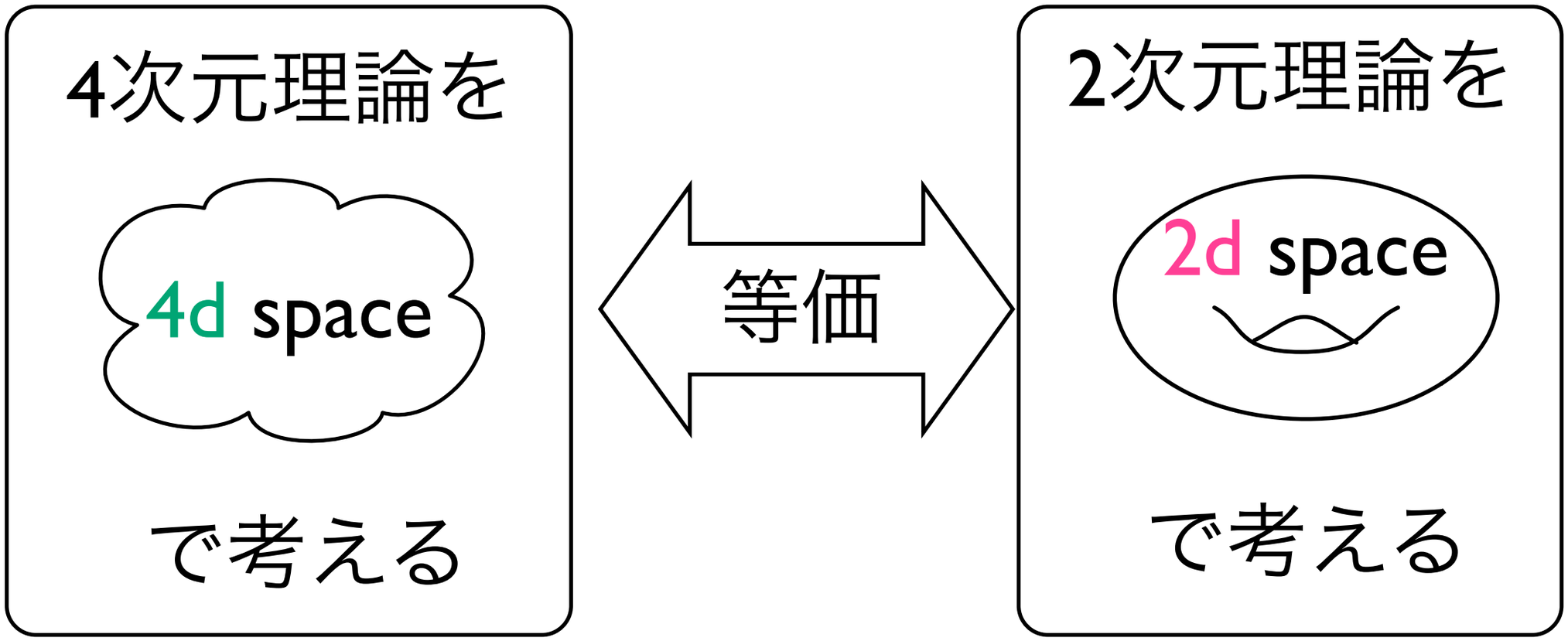

で考える

等価

2次元理論を




で考える




4次元ゲージ理論　　2次元共形場理論

双方とも30年近く研究されていたが、
等価である側面がみつかったのは数年前。

4次元ゲージ理論　　2次元共形場理論

双方とも30年近く研究されていたが、
等価である側面がみつかったのは数年前。

反自己双対接続の
モジュライ空間

W代数の Verma 表現

厳密数学でも長らく研究されていたが
関係の知られていなかった二つのものが
結びつけられた。

# Liouville Correlation Functions from Four-dimensional Gauge Theories

Luis F. Alday, Davide Gaiotto, Yuji Tachikawa

*(Submitted on 17 Jun 2009 (v1), last revised 9 Feb 2010 (this version, v2))*

We conjecture an expression for the Liouville theory conformal blocks and correlation functions on a Riemann surface of genus g and n punctures as the Nekrasov partition function of a certain class of $N$=2 SCFTs recently defined by one of the authors. We conduct extensive tests of the conjecture at genus 0,1.

# Cherednik algebras, W algebras and the equivariant cohomology of the moduli space of instantons on $A^2$

Olivier Schiffmann, Eric Vasserot

*(Submitted on 13 Feb 2012 (v1), last revised 27 Mar 2012 (this version, v2))*

We construct a representation of the affine W-algebra of $gl_r$ on the equivariant homology space of the moduli space of $U_r$-instantons on $A^2$, and identify the corresponding module. As a corollary we give a proof of a version of the AGT conjecture concerning pure $N$=2 gauge theory for the group SU(r). Another proof has been announced by Maulik and Okounkov. Our approach uses a suitable deformation of the universal enveloping algebra of the Witt algebra $W_{1+\infty}$, which is shown to act on the above homology spaces (for any r) and which specializes to all $W(gl_r)$. This deformation is in turn constructed from a limit, as n tends to infinity, of the spherical degenerate double affine Hecke algebra of $GL_n$.

Mathematics > Algebraic Geometry

# Quantum Groups and Quantum Cohomology

Davesh Maulik, Andrei Okounkov

*(Submitted on 6 Nov 2012)*

In this paper, we study the classical and quantum equivariant cohomology of Nakajima quiver varieties for a general quiver Q. Using a geometric R-matrix formalism, we construct a Hopf algebra $Y_Q$, the Yangian of Q, acting on the cohomology of these varieties, and show several results about their basic structure theory. We prove a formula for quantum multiplication by divisors in terms of this Yangian action. The quantum connection can be identified with the trigonometric Casimir connection for $Y_Q$; equivalently, the divisor operators correspond to certain elements of Baxter subalgebras of $Y_Q$. A key role is played by geometric shift operators which can be identified with the quantum KZ difference connection.

In the second part, we give an extended example of the general theory for moduli spaces of sheaves on $C^2$, framed at infinity. Here, the Yangian action is analyzed explicitly in terms of a free field realization; the corresponding R-matrix is closely related to the reflection operator in Liouville field theory. We show that divisor operators generate the quantum ring, which is identified with the full Baxter subalgebras. As a corollary of our construction, we obtain an action of the W-algebra W(gl(r)) on the equivariant cohomology of rank r moduli spaces, which implies certain conjectures of Alday, Gaiotto, and Tachikawa.

- 僕らの予言から証明まで

  数年

- Higgs さんの予言から実験検証まで

  数十年

- 弦理論は実験で確認できそうにないから云々と批判があるが、そのかわり数学的にいろいろ予言があって、証明されている。

- 研究には紙と鉛筆、
- というよりは最近は Mathematica ばかり使っています。

IPMU-11-0191
CALT-68-2855
MPP-2011-130

# The ABCDEFG of Instantons and W-algebras

Christoph A. Keller[♯], Noppadol Mekareeya[♭], Jaewon Song[♯], and Yuji Tachikawa[♮]

[♯] California Institute of Technology, Pasadena, CA 91125, USA

[♭] Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Föhringer Ring 6, 80805 München, Deutschland

[♮] IPMU, University of Tokyo, Kashiwa, Chiba 277-8583, Japan

**Abstract**

For arbitrary gauge groups, we check at the one-instanton level that the Nekrasov partition function of pure $\mathcal{N} = 2$ super Yang-Mills is equal to the norm of a certain coherent state of the corresponding W-algebra. For non-simply-laced gauge groups, we confirm in particular that the coherent state is in the twisted sector of a simply-laced W-algebra.

## D.2 Explicit generators

In the following, we list the generators thus constructed; we set $J = J_5$, $A_i = U^{(i)} + \tilde{U}^{(i)}$ and $B_i = U^{(i)} - \tilde{U}^{(i)}$. With explicit generators, it is easy to check that the level-1 contribution to the norm of the coherent state as calculated by (4.12) is equal to the 1-instanton result (2.9), once when the zero modes are substituted with random numbers.

### D.2.1 $W_2$



### D.2.2 $W_5$



### D.2.3 $W_6$



### D.2.4 $W_8$

### D.2.5 $W_9$

### D.2.6 $W_{12}$

## D.2.2 $W_5$



## D.2.3 $W_6$

## D.2.4 $W_8$

## D.2.5 $W_9$

## D.2.6 $W_{12}$

$$(Q\partial JA_2B_3^2)/\sqrt{(6)}+2\sqrt{(6)}Q\partial JB_3^2T+(2/3+8Q^2)\partial^2JJT^2+(2\sqrt{(6)}Q+24\sqrt{(6)}Q^3)\partial^2JJ^2\partial T+((-19Q)/\sqrt{(6)}-83\sqrt{(2/3)}Q^3)\partial^2JJ^2\partial A_2+(5/\sqrt{(6)}+3\sqrt{(6)}Q^2)\partial^2JJ^2A_3+(4/3+66Q^2/3)\partial^2JJA_2T+(-1/6-3Q^2)\partial^2JJA_3^2+(5/6+5Q^2)\partial^2JJB_3^2+(-16\sqrt{(2/3)}Q-54\sqrt{(6)}Q^3)\partial^2J\partial J\ldots$$
$$8Q\partial JJ^3A_3-2\sqrt{(2/3)}Q\partial J^2A_2T+\sqrt{(2/3)}Q\partial J^2A_2^2+4\sqrt{(2/3)}Q\partial J^2B_3^2+(-2/3-8Q^2)(\partial J)^2J^2T+(2(\partial J)^2J^2A_2)/3+((-8\sqrt{(2/3)}Q)/3-32\sqrt{(2/3)}Q^3)(\partial J)^3J^2+(-4/9-15Q^2/3)\partial^2JJ^3T+(2/3+38Q^2/9)\partial^2J^3A_2+((-13\sqrt{(2/3)}Q)/3-52\sqrt{(2/3)}Q^3)\partial^2J\partial JJ^3+((-4\sqrt{(2/3)}Q$$

# D.2.5 $W_9$

$$W_9=(12959Q/45360+9517Q^3/756+106687Q^5/126+10966Q^7)\partial^7B_2+(-323/540-1847Q^2/60-28349Q^4/30-6594Q^6)\partial^6B_3+((2\sqrt{(2/3)}Q^2)/45-(12044\sqrt{(2/3)}Q^4)/15-4396\sqrt{(6)}Q^6)J\partial^6B_2+((-271\sqrt{(2/3)}Q)/45+(6598\sqrt{(2/3)}Q^3)/15+2222\sqrt{(6)}Q^5)J\partial^5B_3+((-1309Q^2)/(60\sqrt{(6)}$$
$$((-1429Q^2)/(135\sqrt{(6)})-(9829\sqrt{(2/3)}Q^4)/45-2186\sqrt{(2/3)}Q^6)\partial^6JB_2+((-23Q)/72-884Q^3/45-9601Q^5/3)A_2\partial^5B_2+(74/27+4187Q^2/18+2379Q^4)A_2\partial^4B_3+(25Q/36-1123Q^3/3-5985Q^5)\partial A_2\partial^4B_2+(113/27+4189Q^2/9+6064Q^4)\partial A_2\partial^3B_3+(25Q/18-2062Q^3/9-9650Q$$
$$13358Q^3/9-19710Q^5)\partial B_2\partial^4T+((-80Q)/3-7096Q^3/3-35336Q^5)\partial^2B_2\partial^3T+((-292Q)/27-1849Q^3-95964Q^5/3)\partial^3B_2\partial^2T+((-65Q)/9-2674Q^3/3-15948Q^5)\partial^4B_2\partial T+((-2857Q)/540-3791Q^3/15-12934Q^5/3)\partial^5B_2T+(-79/18-638Q^3/3-2150Q^4)B_2\partial^4T+(-242/27-16$$
$$144\sqrt{(6)}Q^3J\partial A_3\partial^2B_2-36\sqrt{(6)}Q^2J\partial A_3\partial B_3+(6\sqrt{(6)}Q+144\sqrt{(6)}Q^3)J\partial^2A_3\partial B_2-36\sqrt{(6)}Q^2J\partial^2A_3B_3+(-2\sqrt{(6)}Q+24\sqrt{(6)}Q^3)J\partial^3A_3B_2+(79/(9\sqrt{(6)})+(566\sqrt{(2/3)}Q^2)/3+1150\sqrt{(2/3)}Q^4)JB_2\partial^4T+((242\sqrt{(2/3)})/27+(5776\sqrt{(2/3)}Q^2)/9+8888\sqrt{(2/3)}Q^4)J\partial B_2\partial^3T+((59\sqrt{(2/3)}$$
$$((272\sqrt{(2/3)}Q)/3+1936\sqrt{(2/3)}Q^3)\partial JA_2\partial B_3+((436\sqrt{(2/3)}Q^2)/3+2873\sqrt{(2/3)}Q^4)\partial J\partial^2A_2\partial B_2+(24\sqrt{(6)}Q+621\sqrt{(6)}Q^3)\partial J\partial^2A_2B_3+((313\sqrt{(2/3)}Q^2)/3+2057\sqrt{(2/3)}Q^4)\partial J\partial^3A_2B_2+((-298\sqrt{(2/3)}Q)/3-2021\sqrt{(2/3)}Q^3)\partial JA_3\partial^3B_2-18\sqrt{(6)}Q^2\partial JA_3\partial B_3+((-596\sqrt{(2/3)}Q)/3-409$$
$$8008Q^4)\partial^2J\partial JBB_3+(1303Q/18+8398Q^3/3+25182Q^5)\partial^2J\partial^2BB_2+(-91/6-338Q^2-954Q^4)\partial^2J\partial^2JB_3+((1986\sqrt{(2/3)}Q^2)/9+(11450\sqrt{(2/3)}Q^4)/3)\partial^2JA_2\partial^2B_2+((-32\sqrt{(2/3)}Q)/3+272\sqrt{(2/3)}Q^3)\partial^2JA_2\partial B_3+(152\sqrt{(2/3)}Q^2+946\sqrt{(6)}Q^4)\partial^2J\partial A_2\partial B_2+(28\sqrt{(6)}Q+666\sqrt{(6)}Q^3)$$
$$(1177Q/27+1722Q^3+49544Q^5/3)\partial^3J\partial^2JB_2+((683\sqrt{(2/3)}Q^2)/9+(4567\sqrt{(2/3)}Q^4)/3)\partial^3JA_2\partial B_2+(12\sqrt{(6)}Q+177\sqrt{(6)}Q^3)\partial^3JA_2B_3+((317\sqrt{(2/3)}Q^2)/3+1681\sqrt{(2/3)}Q^4)\partial^3J\partial A_2B_2+((-230\sqrt{(2/3)}Q)/3-1165\sqrt{(2/3)}Q^3)\partial^3JA_3B_2+((170\sqrt{(2/3)})/9+596\sqrt{(2/3)}Q^2+4564\sqrt{(2/3)}Q^4$$
$$(856Q/9+5864Q^3/3)A_2\partial^2B_2\partial T+(24Q+726Q^3)A_2\partial^3B_2T+(68/3+358Q^2)A_2B_3\partial^2T+(104/9+1636Q^2/3)A_2\partial B_3\partial T+(188/9+418Q^2/3)A_2\partial^2B_3T+(152Q/9+1536Q^3/3)\partial A_2A_2\partial^2B_2+(-214/9-2114Q^2/3)\partial A_2A_2\partial B_3+6Q\partial A_2\partial A_2\partial B_2+(-10-296Q^2)\partial A_2\partial A_2B_3+(4+256Q^2$$
$$108QA_3\partial B_3T-18Q\partial A_3A_3B_2+(16+132Q^2)\partial A_3B_2\partial T+(16/9+1016Q^2/3)\partial A_3\partial B_2T-36Q\partial A_3B_3T+(116/9+562Q^2/3)\partial^2A_3B_2T+(472Q/9+4376Q^3/3)B_2\partial^2T\partial T+(312Q/9+2680Q^3/3)B_2\partial^3TT+(15B_2^2\partial^2B_3)/2+18QB_2\partial B_3B_3+(72Q+1656Q^3)\partial B_2\partial T\partial T+(892Q/9+7232Q^$$
$$(-10/3-23Q^2)J^2\partial^2A_2B_3+((-19Q)/9-47Q^3/3)J^2\partial^3A_2B_2+(112/9+11Q^2/3)J^2A_3\partial^2B_2+18QJ^2A_3\partial B_3+(8/9-140Q^2/3)J^2\partial A_3\partial B_2+54QJ^2\partial A_3B_3+(58/9+65Q^2/3)J^2\partial^2A_3B_2+(256Q/9+1360Q^3/3)J^2B_3^2T+(226Q/3+1688Q^3/3)J^2\partial B_3\partial^2T+((-184Q)/9-668Q^3/3)$$
$$((52\sqrt{(2/3)})/9-(694\sqrt{(2/3)}Q^2)/3)J\partial^2A_2B_2T+54\sqrt{(6)}QJA_3B_2\partial T+6\sqrt{(6)}QJA_3\partial B_2T+24\sqrt{(6)}JA_3B_2T+30\sqrt{(6)}QJ\partial A_3B_2T+(-8\sqrt{(2/3)}-160\sqrt{(6)}Q^2)JB_2\partial T\partial T+(-44\sqrt{(2/3)}-232\sqrt{(6)}Q^2)JB_2\partial^2TT+6\sqrt{(6)}QJB_2^2\partial B_3+((-536\sqrt{(2/3)})/9-(4152\sqrt{(2/3)}Q^2)/3)J\partial B_2\partial TT+13$$
$$3976Q^2/3)\partial JJ\partial B_3T+((-59\sqrt{(2/3)})/9+(2264\sqrt{(2/3)}Q^2)/3+6800\sqrt{(6)}Q^4)(\partial J)^2J\partial^2B_2+(-470\sqrt{(2/3)}Q-3130\sqrt{(6)}Q^3)(\partial J)^2J\partial B_3+((-118\sqrt{(2/3)})/27+(3460\sqrt{(2/3)}Q^2)/9+3704\sqrt{(6)}Q^4)(\partial J)^3\partial B_2+(-172\sqrt{(2/3)}Q-1208\sqrt{(6)}Q^3)(\partial J)^3B_3+((-754Q)/9-5102Q^3/3)(\partial J)^2A_2\partial B_2$$
$$(1721\sqrt{(2/3)}Q^2)/9+(19834\sqrt{(2/3)}Q^4)/3)\partial^2JJ^2B_2+(-90\sqrt{(6)}Q-1488\sqrt{(6)}Q^3)\partial^2JJ\partial B_3+((-1060Q)/9-5768Q^3/3)\partial^2JJA_2\partial B_2+(68/3+340Q^2)\partial^2JJA_2B_3+((-388Q)/9-1686Q^3/3)\partial^2J\partial A_2B_2+(100/9+212Q^2/3)\partial^2JA_3B_2+(1696Q/9+11216Q^3/3)\partial^2JB_2\partial T+(208Q/$$
$$1196Q^3/3)\partial^3JJA_2B_2+(748Q/9+3536Q^3/3)\partial^3JJB_2T+((-170\sqrt{(2/3)})/9-(1274\sqrt{(2/3)}Q^2)/3-1352\sqrt{(2/3)}Q^4)\partial^3J\partial JB_2+(-175/(18\sqrt{(6)})-(1156\sqrt{(2/3)}Q^2)/9-(2555\sqrt{(2/3)}Q^4)/3)\partial^4JJB_2-7QA_2^3\partial B_2+7A_2^3B_3-7A_2^3\partial B_2+10QA_2^2B_2\partial T+2QA_2^2\partial B_2T-12A_2^2B_2T+$$
$$((-124\sqrt{(2/3)})/27-(1232\sqrt{(2/3)}Q^2)/9)J^3\partial^2B_2T-40\sqrt{(6)}QJ^3B_2\partial T-28\sqrt{(6)}QJ^3\partial B_2T+5QJ^2A_2^2\partial B_2-6J^2A_2^2B_3+8J^2A_2A_3B_2-40QJ^2A_2B_2\partial T-12QJ^2A_2\partial B_2T-16QJ^2\partial A_2A_2B_2+4QJ^2\partial A_2B_2T-40J^2A_3B_2T-16QJ^2B_2\partial TT-6J^2B_2^2+28QJ^2\partial B_2T^2+21QJ^2\partial B_2$$
$$((-428Q)/3-3028Q^3)(\partial J)^2JB_2+((-1144Q)/9-6128Q^3/3)\partial^2J^2\partial B_2+(28+272Q^2)\partial^2JJ^2B_3+((152\sqrt{(2/3)})/9+(502\sqrt{(2/3)}Q^2)/3)\partial^2JJ^2A_2B_2+((-200\sqrt{(2/3)})/9-(772\sqrt{(2/3)}Q^2)/3)\partial^2JJ^2B_2T+((-2404Q)/9-14300Q^3/3)\partial^2J\partial JJ^2B_2+((-934Q)/27-4448Q^3/9)\partial^3JJ^3B_2+$$

# D.2.6 $W_{12}$

$$W_{12}=(-1/972-49571Q^2/85050-276929Q^4/85050-271978Q^6/225-3015164Q^8/135-415184Q^{10}/3)\partial^{10}T+(1147Q/(8748\sqrt{(6)})+176479Q^3/(8019\sqrt{(6)})+785407Q^5/(5346\sqrt{(6)})+4130682Q^7/(891\sqrt{(6)})+(33314140\sqrt{(2/3)}Q^9)/99+586040\sqrt{(6)}Q^{11})\partial^{11}J+(-53377/2449440-2141653Q^2/(1$$
$$21424\sqrt{(6)}Q^3)J\partial^9T+(83761Q/(102060\sqrt{(6)})+945239Q^3/(972\sqrt{(6)})+(1104512\sqrt{(2/3)}Q^5)/945+(11322572\sqrt{(2/3)}Q^7)/945+44896\sqrt{(2/3)}Q^9)J\partial^9A_2+((-1685Q^2)/(21\sqrt{(6)})-(3011\sqrt{(2/3)}Q^4)/5-(18916\sqrt{(6)}Q^6)/7-10704\sqrt{(6)}Q^8)J\partial^8A_3+((-1027Q)/(630\sqrt{(6)})-(130642\sqrt{(2/3)}Q^3)/315-(1$$
$$((-31679Q)/(1215\sqrt{(6)})-(1487107\sqrt{(2/3)}Q^3)/405-(4490302\sqrt{(2/3)}Q^5)/27-(12478836\sqrt{(2/3)}Q^7)/45-15883280\sqrt{(2/3)}Q^9)\partial^3J\partial^6T+((-15584\sqrt{(2/3)}Q)/1215-404131Q^3/(135\sqrt{(6)})-8020853Q^5/(45\sqrt{(6)})-(84788467\sqrt{2/3)}Q^7)/45-12146848\sqrt{(2/3)}Q^9)\partial^3J\partial^5A_2+((-44611Q^2)/(45\sqrt{(6)}$$
$$79378824Q^{10})\partial^5J\partial^5J+((-38227\sqrt{(2/3)}Q)/1215-2178823Q^3/(270\sqrt{(6)})-(116186081Q^5/(270\sqrt{(6)})-(12942434\sqrt{(2/3)}Q^7)/3-(83474680\sqrt{(2/3)}Q^9)/3)\partial^5J\partial^4A_2+((-121958\sqrt{(2/3)}Q^2)/135-1990069Q^4/(45\sqrt{(6)})-(2922478\sqrt{(2/3)}Q^6)/15-646856\sqrt{(2/3)}Q^8)\partial^5J\partial^5A_3+((-45218\sqrt{(2/3)}Q)/$$
$$1382035856Q^8/105+75670816Q^{10})\partial^7J\partial^3J+((-368737Q)/(8505\sqrt{(6)})-14665961Q^3/(2835\sqrt{(6)})-(112620028\sqrt{(2/3)}Q^5)/945-(693397004\sqrt{(2/3)}Q^7)/315-4430432\sqrt{(6)}Q^9)\partial^7J\partial^2A_2+((-2737Q^2)/(9\sqrt{(6)})-(1108687\sqrt{(2/3)}Q^4)/315-(3139472\sqrt{(2/3)}Q^6)/105-33072\sqrt{(6)}Q^8)\partial^7J\partial A_3+(1$$
$$6505123Q^4/3402+1215655Q^6/162+2333900332Q^8/189+695608Q^{10})\partial^8J\partial J+((-400279Q)/(5103\sqrt{(6)})-627329Q^3/(567\sqrt{(6)})-155800847Q^5/(3670\sqrt{(6)})-(207834586\sqrt{(2/3)}Q^7)/945-(3654206\sqrt{(2/3)}Q^9)/3)\partial^9JA_2+(-113/5103-1693Q^2/8505-129568Q^4/1215-2590996Q^6/945-32282$$
$$7673648Q^8/3)\partial^4A_2\partial^4T+(17875/972+2707Q^2/6+393746Q^4/27+818896Q^6/3+4912984Q^8/3)\partial^4A_2\partial^4A_2+(314Q/81-31568Q^3/27-242366Q^5/9-418648Q^7/3)\partial^4A_2\partial^3A_3+(236/405+13897GQ^2/405+58475Q^4/3+1716621GQ^6/45+23537920Q^8)\partial^5A_2\partial^3T+(30343/972+1321037Q^2/1620+25$$
$$1581758Q^6/63+138392Q^8)\partial^6A_2T+(3047/2835+80743Q^2/1890+76511Q^4/54+212642Q^6/9+133040Q^8)\partial^6A_2A_2+((-73744Q)/2835-202388Q^3/315-1951016Q^5/315-220480Q^7)A_3\partial^7T+((-8143Q)/81-29890Q^3/9-1737990Q^5/45-154336Q^7)\partial A_3\partial^6T+((-7786Q)/45-365011Q^3/45-1$$
$$9209Q^3/15+158Q^5-23688Q^7)\partial B_2\partial^6B_2+(529Q/15+12033Q^3/15+5906Q^5/5-27720Q^7)\partial^2B_2\partial^5B_2+(1133Q/18+19382Q^3/9+18538Q^5+45640Q^7)\partial^3B_2\partial^4B_2+(5177/324+11101Q^2/54-6099TQ^4/18-236206Q^6/3-393046Q^8)\partial^4B_2\partial^4B_2+(1739Q/18+9546Q^3/3+34650Q^5+132072Q^7)\partial^4B$$
$$(-52/15-180Q^2-15996Q^4/5-151200Q^6)\partial^6B_3B_3+((-930Q^2)/3-15440Q^4-141120Q^6)\partial^2T\partial^2T\partial^2T+(-400/27-20128Q^2/9-80704Q^4-672000Q^6)\partial^3T\partial^2T\partial T+(-3800/243-76288Q^2/81-663232Q^4/27-1675520Q^6/5)\partial^3T\partial^3TT+(-2180/243-75976Q^2/81-742792Q^4/27-1895072Q^$$
$$89624Q^8)J^2\partial^8T+(-3503/136080-40583Q^2/6480+315121Q^4/1890+416287Q^6/63+47788Q^8)J^2\partial^8A_2+(1501Q/126+72319Q^3/945+5573Q^5/15+2308Q^7/3)J^2\partial^7A_3+((15238\sqrt{(2/3)}Q)/2835+(71694\sqrt{(2/3)}Q^3)/945+(3685624\sqrt{(2/3)}Q^5)/315+48992\sqrt{(2/3)}Q^7)JA_2\partial^7T+((5272\sqrt{(2/3)}Q^$$
$$((-18289\sqrt{(2/3)}Q)/81-(206587\sqrt{(2/3)}Q^3)/27-(967616\sqrt{(2/3)}Q^5)/9-(1364096\sqrt{(2/3)}Q^7)/3)J\partial^4A_2\partial^3A_2+((5252\sqrt{(2/3)}Q^2)/9+14348\sqrt{(2/3)}Q^4+76576\sqrt{(2/3)}Q^6)J\partial^4A_2\partial^2A_3+((-2897\sqrt{(2/3)}Q)/135+(2975\sqrt{(2/3)}Q^3)/9+(83686\sqrt{(2/3)}Q^5)/5+118276\sqrt{(2/3)}Q^7)J\partial^5A_2\partial^2T+((-198$$
$$((9212\sqrt{(2/3)})/405+(14972\sqrt{(2/3)}Q^2)/45+(122152\sqrt{(2/3)}Q^4)/45+15864\sqrt{(2/3)}Q^6)JA_3\partial^6T+((2566\sqrt{(2/3)})/45+(66067\sqrt{(2/3)}Q^2)/45+(250472\sqrt{(2/3)}Q^4)/15+22032\sqrt{(6)}Q^6)J\partial A_3\partial^5T+((1408\sqrt{(2/3)})/27+(30314\sqrt{(2/3)}Q^2)/9+(152972\sqrt{(2/3)}Q^4)/3+220240\sqrt{(2/3)}Q^6)J\partial^2A_3\partial^4T+(($$
$$11488\sqrt{(6)}Q^6)J\partial BB_2\partial^5B_2+(106\sqrt{(6)}Q^2+9428\sqrt{(2/3)}Q^4+17360\sqrt{(6)}Q^6)J\partial^2B_2\partial^4B_2+(-96\sqrt{(6)}Q^2+2416\sqrt{(2/3)}Q^4+7744\sqrt{(6)}Q^6)J\partial^3B_2\partial^3B_2+((-878\sqrt{(2/3)}Q)/9+(26692\sqrt{(2/3)}Q^3)/9+70888\sqrt{(2/3)}Q^5+355426\sqrt{(2/3)}Q^7)J\partial^4B_2\partial^3B_2+(-6\sqrt{(6)}Q^2+692\sqrt{(2/3)}Q^4-364\sqrt{(6)}Q^6)J\partial^4B$$
$$(7577920\sqrt{(2/3)}Q^7)/3)\partial J\partial^3T\partial^3T+((24554\sqrt{(2/3)}Q)/81+(774016\sqrt{(2/3)}Q^3)/27+(5788660\sqrt{(2/3)}Q^5)/9+(12361840\sqrt{(2/3)}Q^7)/3)\partial J\partial^4T\partial^2T+((27448\sqrt{(2/3)}Q)/81+(543596\sqrt{(2/3)}Q^3)/27+(3396292\sqrt{(2/3)}Q^5)/9+(6636304\sqrt{(2/3)}Q^7)/3)\partial J\partial^5T\partial T+((56552\sqrt{(2/3)}Q)/405+(955976\sqrt{(2/3)}Q$$
$$(35532\sqrt{(2/3)}Q^4)/5+8214\sqrt{(6)}Q^6)\partial JA_2\partial^5A_3+((79226\sqrt{(2/3)}Q)/405+(3010591\sqrt{(2/3)}Q^3)/135+(20149878\sqrt{(2/3)}Q^5)/45+(7739812\sqrt{(2/3)}Q^7)/3)\partial J\partial A_2\partial^5T+(6563Q^2/(3\sqrt{(6)})+3669\sqrt{(6)}Q^4+3462\sqrt{(6)}Q^6)\partial J\partial A_2\partial^4A_3+((11831\sqrt{(2/3)}Q)/81+(986206\sqrt{(2/3)}Q^3)/27+(7446322\sqrt{(2/3)}Q^5)/$$
$$((10210\sqrt{(2/3)}Q)/81+(1975783\sqrt{(2/3)}Q^3)/135+(15417418\sqrt{(2/3)}Q^5)/45+(6657064\sqrt{(2/3)}Q^7)/3)\partial J\partial^5A_2\partial T+(104471Q/(810\sqrt{(6)})+1974631Q^3/(135\sqrt{(6)})+19631687Q^5/(45\sqrt{(6)})+(6925248\sqrt{(2/3)}Q^7)/3)\partial J\partial^5A_2\partial A_2+(25\sqrt{(6)}Q^2+8387Q^4/(15\sqrt{(6)})-422\sqrt{(2/3)}Q^6)\partial J\partial^5A_2A_3+((8686\sqrt{(}$$
$$((-208\sqrt{(2/3)})/9+(17483\sqrt{(2/3)}Q^2)/9+13720\sqrt{(2/3)}Q^4-24992\sqrt{(2/3)}Q^6)J\partial\partial^4A_3\partial T+((-5399Q)/(9\sqrt{(6)})-775\sqrt{(6)}Q^3-6820\sqrt{(2/3)}Q^5)J\partial\partial^4A_3A_3+((56\sqrt{(2/3)})/45+(43522\sqrt{(2/3)}Q^2)/45+(18252\sqrt{(6)}Q^4)/5+26080\sqrt{(2/3)}Q^6)J\partial\partial^5A_3T+((-2305\sqrt{(2/3)}Q^2)/9-(3431\sqrt{(2/3)}Q^4)/5+8$$
$$(15143Q/(270\sqrt{(6)})+(49346\sqrt{(2/3)}Q^3)/45+103721Q^5/(5\sqrt{(6)})+31262\sqrt{(2/3)}Q^7)\partial J\partial^6B_2B_2+(-508\sqrt{(2/3)}Q-2962\sqrt{(6)}Q^3-15924\sqrt{(6)}Q^5)\partial J\partial^2B_2\partial^2B_2+((-1591\sqrt{(2/3)}Q)/3-4356\sqrt{(6)}Q^3-23276\sqrt{(6)}Q^5)\partial J\partial^3B_2\partial B_2+((-1607Q)/(3\sqrt{(6)})-1950\sqrt{(6)}Q^3-8048\sqrt{(6)}Q^5)\partial J\partial^4B_2B_2+((17$$
$$8337412Q^4/135-1188970Q^6=7684164Q^8)\partial^2JJ\partial J^5A_2+(6811Q/27-130033Q^3/27-346046Q^5/3-1040912Q^7/3)\partial^2JJ\partial^4A_2+(163/81+81638Q^2/81-737512Q^4/81-2549800Q^6/3-6893664Q^8/9)\partial^2J\partial^2J\partial^4T+(163/81-3157852Q^2/162-7856950Q^4/81-17520487Q^6/9-11338546Q^8$$
$$(14719694\sqrt{(2/3)}Q^5)/9+10515340\sqrt{(2/3)}Q^7)\partial^2J\partial^3A_2\partial^2T+((5581\sqrt{(2/3)}Q)/27+1657241Q^3/(27\sqrt{(6)})+(8640886\sqrt{(2/3)}Q^5)/9+7394384\sqrt{(2/3)}Q^7)\partial^2J\partial^3A_2\partial^2A_2+((-656\sqrt{(2/3)}Q^2)/3-10330\sqrt{(2/3)}Q^4-56972\sqrt{(2/3)}Q^6)\partial^2J\partial^3A_2\partial A_3+((29348\sqrt{(2/3)}Q)/81+(281980\sqrt{(2/3)}Q^3)/9+97638$$
$$(112240\sqrt{(2/3)}Q^4)/3-67768\sqrt{(6)}Q^6)\partial^2J\partial^2A_3\partial^2T+((-278\sqrt{(2/3)}Q)/3+13567\sqrt{(2/3)}Q^3+19912\sqrt{(6)}Q^5)\partial^2J\partial^2A_3\partial A_3+((2108\sqrt{(2/3)})/27+(31736\sqrt{(2/3)}Q^2)/9-2168\sqrt{(2/3)}Q^4-103864\sqrt{(2/3)}Q^6)\partial^2J\partial^3A_3\partial T+((-1118\sqrt{(2/3)}Q)/3+1027\sqrt{(2/3)}Q^3+4132\sqrt{(6)}Q^5)\partial^2J\partial^3A_3A_3+((272$$
$$561089Q^3/(90\sqrt{(6)})+182717Q^5/(3\sqrt{(6)})+106538\sqrt{(2/3)}Q^7)\partial^2J\partial^5B_2B_2+((-5824\sqrt{(2/3)}Q)/3-15046\sqrt{(6)}Q^3-65324\sqrt{(6)}Q^5)\partial^2J\partial^2B_2\partial B_2+((-2600\sqrt{(2/3)}Q)/3-5446\sqrt{(6)}Q^3-22648\sqrt{(6)}Q^5)\partial^2J\partial^3B_2B_2+((19840\sqrt{(2/3)}Q)/27+(337616\sqrt{(2/3)}Q^3)/9+(2661584\sqrt{(2/3)}Q^5)/3+5938240\sqrt{$$
$$10138Q^3/9-66214Q^5+50084Q^7)\partial^3J\partial J\partial^3A_2+(932/81+142626Q^2/81-2477828Q^4/27-3377587TQ^6/9-87062083Q^8/3)\partial^3J\partial^2J\partial^3T+(932/81-526726Q^2/81-8850612Q^4/27-58567162Q^6/9-125493380Q^8/3)\partial^3J\partial^2J\partial^3A_2+(15482Q/9+413102Q^3/27+244336Q^5/9+4413246Q^7)\partial^3J\partial^2J\partial^2$$

# D.2.6 $W_{12}$

$$W_{12} = (-1/972-49571Q^2/85050-2769829Q^4/85050-271978Q^6/225-3015164Q^8/135-415184Q^{10}/3)\partial^{10}T+(1147Q/(8748\sqrt{(6)})+176479$$
$$21424\sqrt{(6)}Q^9)J\partial^9T+(83761Q/(102060\sqrt{(6)})+94523Q^3/(972\sqrt{(6)})+(1104512\sqrt{(2/3)}Q^5)/945+(11322572\sqrt{(2/3)}Q^7)/945+44096\sqrt{(2/3)}Q^9$$
$$((-31679Q)/(1215\sqrt{(6)})-(1487107\sqrt{(2/3)}Q^3)/405-(4400302\sqrt{(2/3)}Q^5)/27-(124788356\sqrt{(2/3)}Q^7)/45-15883280\sqrt{(2/3)}Q^9)\partial^3J\partial^6T+((($$
$$79378824Q^{10})\partial^5J\partial^5J+((-38227\sqrt{(2/3)}Q)/1215-2176823Q^3/(270\sqrt{(6)})-116184061Q^5/(270\sqrt{(6)})-(12942424\sqrt{(2/3)}Q^7)/3-(81474680\sqrt{}$$
$$1382035856Q^8/105+75670816Q^{10})\partial^7J\partial^3J+((-368737Q)/(8505\sqrt{(6)})-14665961Q^3/(2835\sqrt{(6)})-(112620028\sqrt{(2/3)}Q^5)/945-(69339700$$
$$6505123Q^4/3402+12156655Q^6/162+233390032Q^8/189+6956008Q^{10})\partial^9J\partial J+((-400279Q)/(51030\sqrt{(6)})-6278329Q^3/(8505\sqrt{(6)})-155800$$
$$7673648Q^8/3)\partial^4A_2\partial^4T+(17875/972+2707Q^2/6+393748Q^4/27+818894Q^6/3+4912984Q^8/3)\partial^4A_2\partial^4A_2+(314Q/81-31568Q^3/27-24236$$
$$1581758Q^6/63+138392Q^8)\partial^8A_2T+(3047/2835+80743Q^2/1890+76511Q^4/54+212642Q^6/9+133040Q^8)\partial^8A_2A_2+((-73744Q)/2835-202$$
$$9298Q^3/15+158Q^5-23688Q^7)\partial B_2\partial^6B_3+(529Q/15+12023Q^3/15+5906Q^5/5-27720Q^7)\partial^2B_2\partial^5B_3+(1133Q/18+19382Q^3/9+18538Q^5+$$
$$(-52/15-180Q^2-15996Q^4/5-15120Q^6)\partial^6B_3B_3+((-920Q^2)/3-15440Q^4-141120Q^6)\partial^2T\partial^2T\partial^2T+(-400/27-20128Q^2/9-80704Q^4$$
$$89624Q^8)J^2\partial^8T+(-3503/136080-40583Q^2/6480+315121Q^4/1890+416287Q^6/63+47788Q^8)J^2\partial^8A_2+(1501Q/126+72319Q^3/945+557$$
$$((-18289\sqrt{(2/3)}Q)/81-(206587\sqrt{(2/3)}Q^3)/27-(967616\sqrt{(2/3)}Q^5)/9-(1364096\sqrt{(2/3)}Q^7)/3)J\partial^4A_2\partial^3A_2+((5252\sqrt{(2/3)}Q^2)/9+14348$$
$$((9212\sqrt{(2/3)})/405+(14972\sqrt{(2/3)}Q^2)/45+(122152\sqrt{(2/3)}Q^4)/45+10064\sqrt{(2/3)}Q^6)JA_3\partial^6T+((2566\sqrt{(2/3)})/45+(66067\sqrt{(2/3)}Q^2)/45+$$
$$11488\sqrt{(6)}Q^6)J\partial B_2\partial^5B_3+(106\sqrt{(6)}Q^2+9428\sqrt{(2/3)}Q^4+17360\sqrt{(6)}Q^6)J\partial^2B_2\partial^4B_3+(-96\sqrt{(6)}Q^2+2416\sqrt{(2/3)}Q^4+7744\sqrt{(6)}Q^6)J\partial^3B$$
$$(7577920\sqrt{(2/3)}Q^7)/3)\partial J\partial^3T\partial^3T+((24554\sqrt{(2/3)}Q)/81+(774016\sqrt{(2/3)}Q^3)/27+(5788660\sqrt{(2/3)}Q^5)/9+(12341840\sqrt{(2/3)}Q^7)/3)\partial J\partial^4T\partial$$
$$(35332\sqrt{(2/3)}Q^4)/5+8214\sqrt{(6)}Q^6)\partial JA_2\partial^5A_3+((73226\sqrt{(2/3)}Q)/405+(3010591\sqrt{(2/3)}Q^3)/135+(20149876\sqrt{(2/3)}Q^5)/45+(7739812\sqrt{(2/3}$$
$$((10210\sqrt{(2/3)}Q)/81+(1975783\sqrt{(2/3)}Q^3)/135+(15417418\sqrt{(2/3)}Q^5)/45+(6657064\sqrt{(2/3)}Q^7)/3)\partial J\partial^5A_2\partial T+(104471Q/(810\sqrt{(6)})+1974$$
$$((-208\sqrt{(2/3)})/9+(17483\sqrt{(2/3)}Q^2)/9+13720\sqrt{(2/3)}Q^4-24992\sqrt{(2/3)}Q^6)\partial J\partial^4A_3\partial T+((-5399Q)/(9\sqrt{(6)})-775\sqrt{(6)}Q^3-4820\sqrt{(2/3)}Q^5$$
$$(15143Q/(270\sqrt{(6)}))+(49346\sqrt{(2/3)}Q^3)/45+103721Q^5/(5\sqrt{(6)})+31262\sqrt{(2/3)}Q^7)\partial J\partial^6B_2B_2+(-508\sqrt{(2/3)}Q-2942\sqrt{(6)}Q^3-15924\sqrt{(6)}Q$$
$$8337412Q^4/135-11888070Q^6-76814168Q^8)\partial^2J\partial J\partial^5A_2+(6811Q/27-130933Q^3/27-346048Q^5/3-1040912Q^7/3)\partial^2J\partial J\partial^4A_2+(163/81$$

$$W_{12} = (-1/972 - 49571Q^2/85050 - 2769829Q^4/85050 - 271978Q^6/225 - 3015164Q^8/135 -$$
$$21424\sqrt{(6)}Q^9)J\partial^9 T + (83761Q/(102060\sqrt{(6)}) + 94523Q^3/(972\sqrt{(6)}) + (1104512\sqrt{(2/3)}Q^5)/$$
$$((-31679Q)/(1215\sqrt{(6)}) - (1487107\sqrt{(2/3)}Q^3)/405 - (4400302\sqrt{(2/3)}Q^5)/27 - (124788356$$
$$79378824Q^{10})\partial^5 J\partial^5 J + ((-38227\sqrt{(2/3)}Q)/1215 - 2176823Q^3/(270\sqrt{(6)}) - 116184061Q^5/$$
$$13820358 56Q^8/105 + 75670816Q^{10})\partial^7 J\partial^3 J + ((-368737Q)/(8505\sqrt{(6)}) - 14665961Q^3/(28$$
$$6505123Q^4/3402 + 12156655Q^6/162 + 233900 32Q^8/189 + 6956008Q^{10})\partial^9 J\partial J + ((-400279Q$$
$$7673648Q^8/3)\partial^4 A_2\partial^4 T + (17875/972 + 2707Q^2/6 + 393748Q^4/27 + 818894Q^6/3 + 4912984Q$$
$$1581758Q^6/63 + 138392Q^8)\partial^8 A_2 T + (3047/2835 + 80743Q^2/1890 + 76511Q^4/54 + 212642Q^6$$
$$9298Q^3/15 + 158Q^5 - 23688Q^7)\partial B_2\partial^6 B_3 + (529Q/15 + 12023Q^3/15 + 5906Q^5/5 - 27720Q^7)$$
$$(-52/15 - 180Q^2 - 15996Q^4/5 - 15120Q^6)\partial^6 B_3 B_3 + ((-920Q^2)/3 - 15440Q^4 - 141120Q^6)$$
$$89624Q^8)J^2\partial^8 T + (-3503/136080 - 40583Q^2/6480 + 315121Q^4/1890 + 416287Q^6/63 + 477$$
$$((-18289\sqrt{(2/3)}Q)/81 - (206587\sqrt{(2/3)}Q^3)/27 - (967616\sqrt{(2/3)}Q^5)/9 - (1364096\sqrt{(2/3)}Q$$
$$((9212\sqrt{(2/3)}))/405 + (14972\sqrt{(2/3)}Q^2)/45 + (122152\sqrt{(2/3)}Q^4)/45 + 10064\sqrt{(2/3)}Q^6)JA_3$$
$$11488\sqrt{(6)}Q^6)J\partial B_2\partial^5 B_3 + (106\sqrt{(6)}Q^2 + 9428\sqrt{(2/3)}Q^4 + 17360\sqrt{(6)}Q^6)J\partial^2 B_2\partial^4 B_3 + ($$
$$(7577920\sqrt{(2/3)}Q^7)/3)\partial J\partial^3 T\partial^3 T + ((24554\sqrt{(2/3)}Q)/81 + (774016\sqrt{(2/3)}Q^3)/27 + (57886$$

- 普通の文字サイズだと式だけで60頁ぐらい。
- 共同研究者とプログラムに一週間、計算はパソコンで一晩かかった。

- この式は重要でない中間結果。
- これがある綺麗な性質を満たすというのが確認したかったことなので、計算せざるを得なかった。

弦理論/場の量子論
(いいかげん)

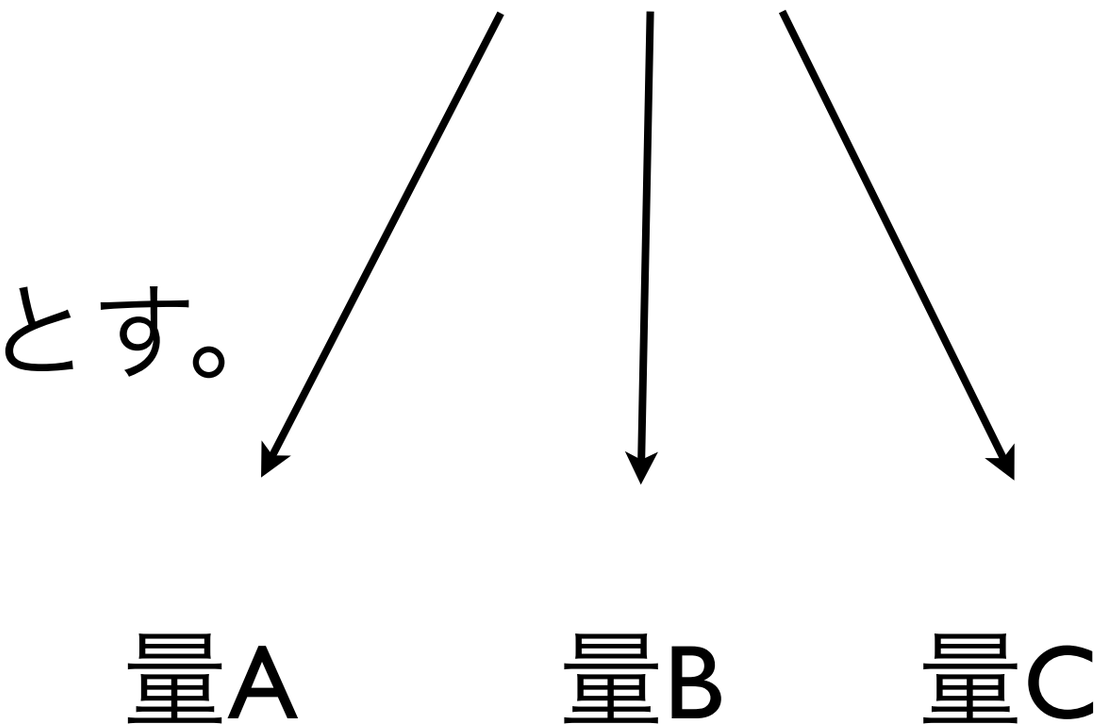
ある一つの「物理量」

弦理論/場の量子論
(いいかげん)

何通りもの方法で、

厳密に計算できる量に落とす。

数学
(厳密)

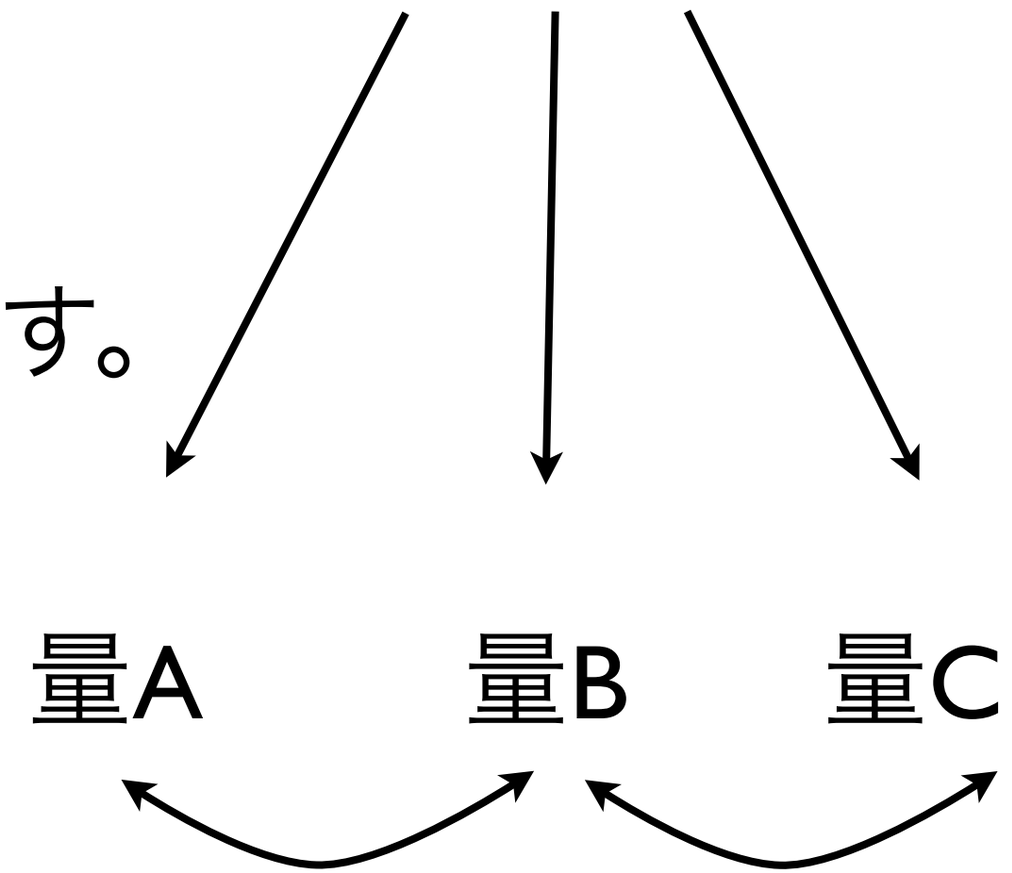


弦理論/場の量子論
(いいかげん)

何通りもの方法で、

厳密に計算できる量に落とす。

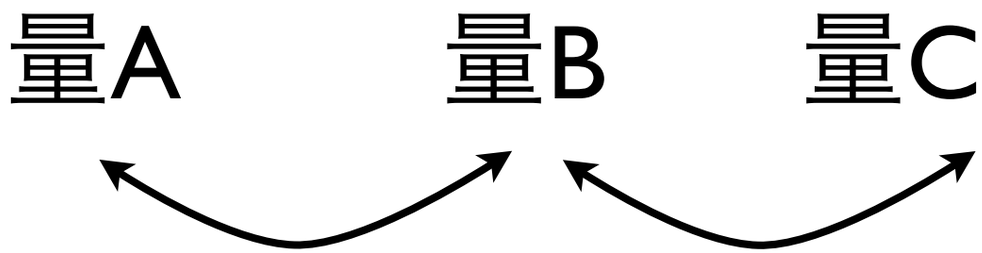
数学
(厳密)




元々一つのものだから等価。

数学者には謎に見える。

数学
(厳密)



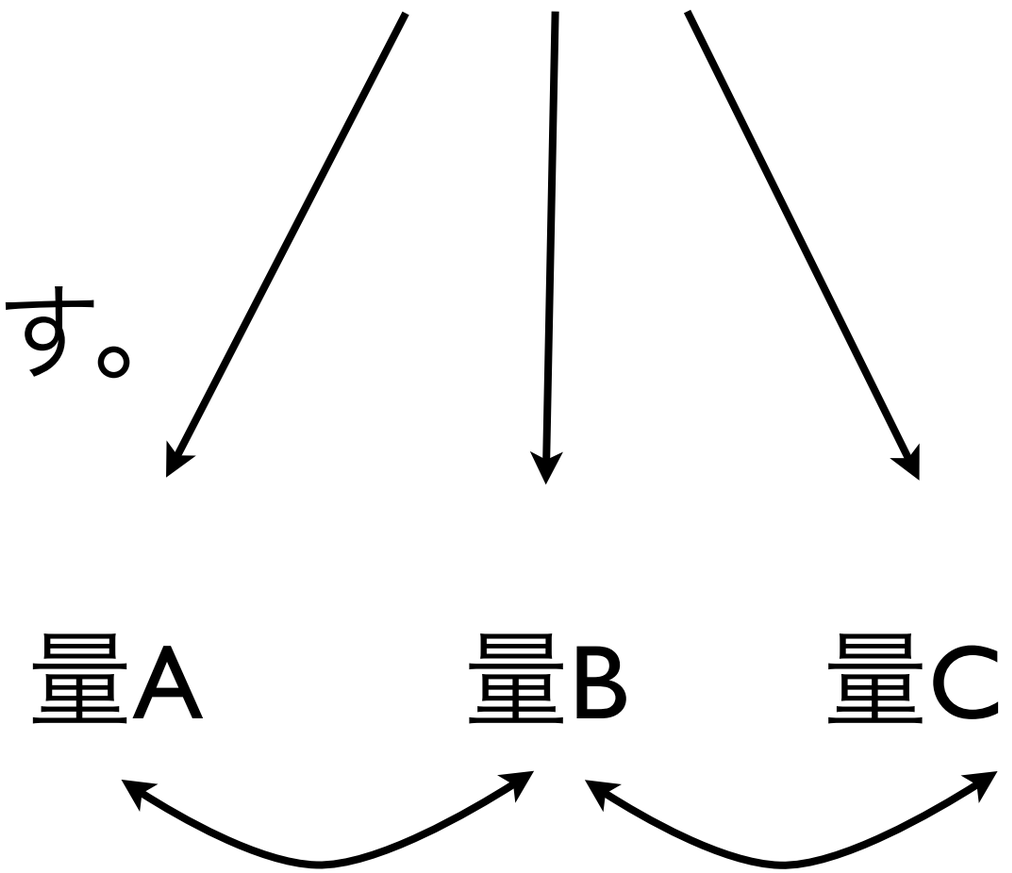

元々一つのものだから等価。
数学者には謎に見える。

弦理論/場の量子論
(いいかげん)

何通りもの方法で、

厳密に計算できる量に落とす。

数学
(厳密)



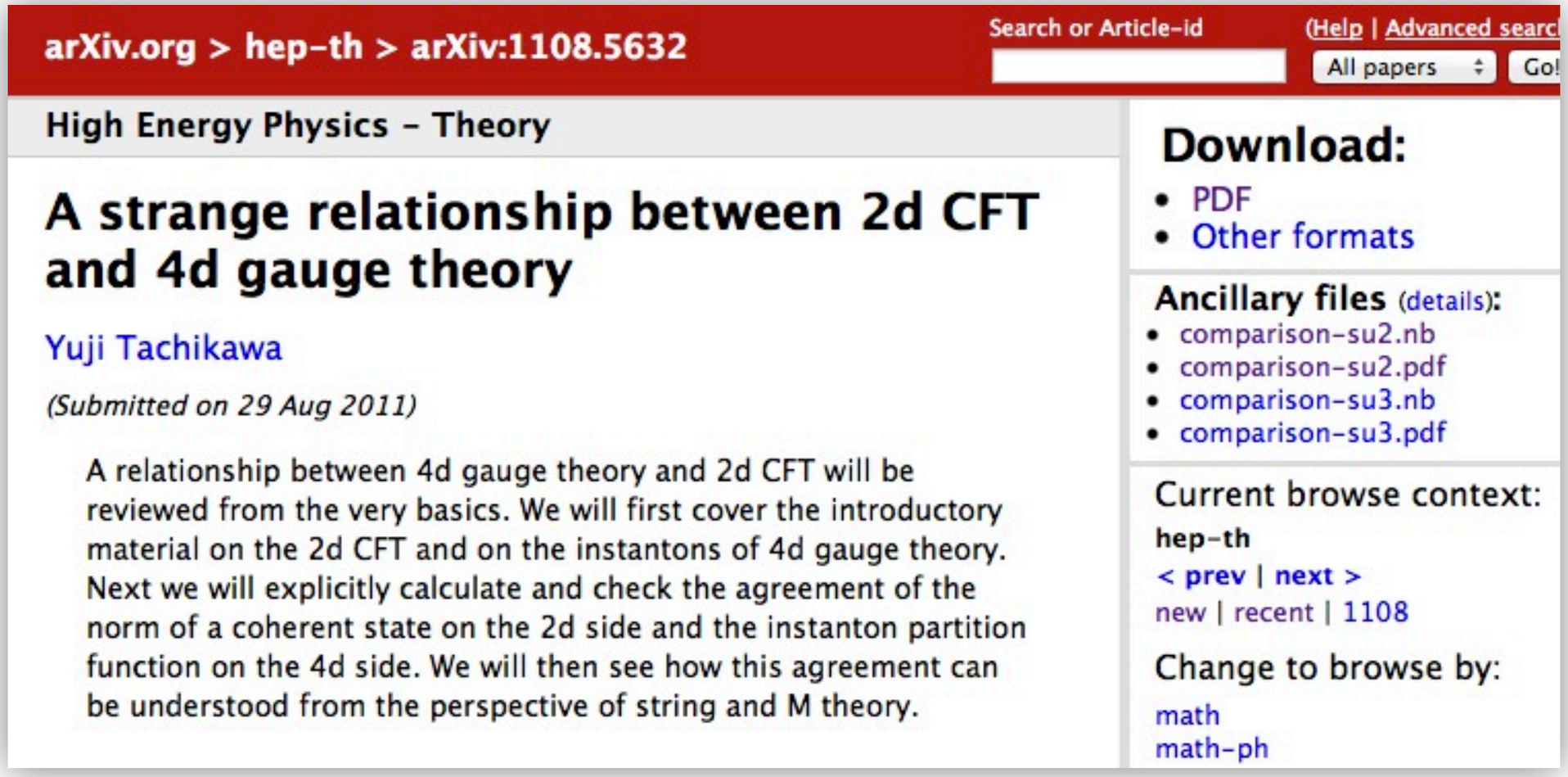

元々一つのものだから等価。

数学者には謎に見える。

- 数学的に厳密に場の量子論をやるというわけではないです。

- むしろ、場の量子論/弦理論の性質を良く調べるということが重要。

- 意欲的な四年生には読める(はず)の日本語の講義録があるので、興味があればどうぞ。




http://arxiv.org/abs/1108.5632

# 四次元ゲージ理論と二次元共形場理論の不思議な関係

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**概要***

近年発見された、四次元ゲージ理論と二次元共形場理論の関係を非常に基礎から解説します。まず、二次元の共形場理論および四次元のインスタントンの入門をした後、二次元側でコヒーレント状態のノルムの計算、四次元側でインスタントンの分配関数を具体的に計算を行って確認します。その後、一致が超弦理論/M理論の枠内でどのように自然に解釈されるかを見ます。

http://arxiv.org/abs/1108.5632