BEING FASCINATED BY STRINGS AND MEMBRANES: IS KIKKAWA-TYPE PHYSICS POSSIBLE AT OCHANOMIZU?

A. SUGAMOTO
Department of Physics, Ochanomizu University,
2-1-1, Otsuka, Bunkyo-ku, Tokyo, 112 Japan

Abstract
On the occasion of the 60th birthday of Professor Keiji Kikkawa, Kikkawa-type physics performed at Ochanomizu was personally reviewed, and the generation of the metric is discussed with the condensation of the string fields.

1 Personal Memories with Professor Keiji Kikkawa and the Kikkawa-Type Physics at Ochanomizu

It is my great pleasure to contribute to the proceedings of the workshop held at Osaka to celebrate the 60th birthday of Professor Keiji Kikkawa. I am very much influenced by his physics, especially by his papers on 1) the light-cone field theory of string (Its Japanese version included in Soryushiron Kenkyu was my favorite.), 2) his lecture note on the superstrings given just before the string fever started (I think everybody should begin with this lecture note when he or she wants to do something in strings.), 3) hadronic strings with quarks at the ends, and 4) the path integral formulation of the Nambu-Jona-Lasinio model. Personally, Professor Kikkawa cited my paper on the dual transformation in gauge theories at the Tokyo conference in 1978, without which I could not have survived in our particle physics community and would definitely be engaged in another job now. Therefore I am greatly indebted to him for his guidance in physics. It was probably 1979 summer when I went abroad for the first time with my late friend Dr. Osamu Sawada, and we stayed at Professor Hirotaka Sugawara’s residence in Honolulu. The topical conference
was held at the moment, and Kikkawa-san came to Honolulu to attend it. Kikkawa-san, Sugawara-san, Sandip Pakvasa-san, Sawada-san, and myself would always sit on the beautiful seashore and the younger ones listened to the physics discussion exchanged between Kikkawa-san and Sugawara-san. The one month stay in Honolulu was one of my great and most stimulating experiences.

At Kikkawa-san’s 60th birthday Conference, everybody was talking about “p-branes and duality transformations”. I really thought we were timeslipping to 15∼20 years ago. At that time “dual transformation, membrane and n-dimensionally extended objects (now called p-branes)” were my favorite themes. If my paper on the membranes (which was the theory of n-branes) gave a little influence on the famous membrane paper by Kikkawa-san and Yamasaki-san, I would be very happy. After moving to Ochanomizu University in 1987 from KEK, I have been working with my students mainly on the phenomenological problems of the non-Kikkawa type physics, including beyond the standard model effects in the $e^+e^- \rightarrow W^+W^-$ process, the effect of the top condensation in B-physics, the neutrino physics, the CP violating models and the baryogenesis of our universe. Postdocs, Yasuhiko Katsuki, Kiusau Teshima, Hirofumi Yamada, Isamu Watanabe, Mohammad Ahmady and Noriyuki Oshimo did their own physics on the beyond the standard model, multiple production in perturbative QCD, non-perturbative QCD, linear collider physics and the two photon process, rare decays and the heavy quark symmetry in B-physics and CP violation in SUSY and SUSY breaking, respectively, with the help of the then students, Miho Marui, Kumiko Kimura, Atsuko Nitta, Azusa Yamaguchi, Fumiko Kanakubo, Tomomi Saito, Tomoko Uesugi, Tomoko Kadoyoshi, Minako Kitahara and Rika Endo. I have, however, sometimes come back to the Kikkawa-type physics on the string, membrane and gravity theories with my postdocs and my students: For example,

(1) Orbifold models were firstly studied with Ikuo Senda.

(2) Using the light-cone gauge field theory of strings invented by Kaku and Kikkawa, we with Miho Marui and Ichiro Oda have derived the Altarelli-Parisi like evolution equation, since the decay function of strings works naturally in this light-cone frame as has happened similarly in QCD.

(3) Knotting of the membrane was studied.

(4) With Ichiro Oda, Akika Nakamichi and Fujie Nagamori, we studied four dimensional topological gravities, mainly on their quantization.

(5) Relating to this topological nature at high energies, estimation of the membrane scattering amplitudes is performed with Sachiko Kokubo, giving an indication of the structural phase transition among the intermediate shapes of the membranes, when the scattering angle is changed.

Other Kikkawa-type physics performed by our postdocs at Ochanomizu were;

(6) Kiyoshi Shiraishi studied some 5 years ago BPS soliton and Born-Infeld theories as well as the finite temperature field theories,
The dilatonic gravity and black holes were investigated by Ichiro Oda and Shin’ichi Nojiri, and

Hybrid model of continuous and discrete theories are examined by Toshiyuki Kuruma.

Recently I am very much interested, as for the Kikkawa-type physics, in

the generation of the Einstein gravity from the topological theory \[4\],

the swimming of microorganisms viewed from string and membrane theories, \[5\] and

phase transition dynamics viewed from the field theoretical membrane theories.

The issue (9) is being investigated with Miyuki Katsuki, Hiroto Kubota, and Shin’ichi Nojiri, the issue (10) is with Masako Kawamura and Shin’ichi Nojiri and is helped by the Barcelona friends, Sergei Odintsov and Emil Elizalde, but the last issue (11) is still at the stage of promoting a vague idea.

In the next section I will mainly explain the issue (9), and will comment on my vague idea of the issue (11).

2 Generation of the Einstein Gravity from the Topological 2-Form Gravity

The topological 2-form gravity is given by the following chiral action for the self-dual part:

\[
S = \int \frac{1}{2} \epsilon^{\mu\nu\lambda\rho} \left( B_{\mu\nu}^a(x) R_{\lambda\rho}^a(x) + \phi^{ab}(x) B_{\mu\nu}^a(x) B_{\lambda\rho}^b(x) \right),
\]

where \( B_{\mu\nu}^a(x) \) is the anti-symmetric tensor field or the Kalb-Ramond field and \( R_{\lambda\rho}^a(x) \) is the \( SU(2) \) field strength for the \( SU(2) \) spin connection \( \omega_{\mu}^a \). The constraint condition expressed by the Lagrange multiplier field \( \phi^{ab}(x) \) can be solved naturally by introducing the vierbein and the t’ Hooft symbol as \( B_{\mu\nu}^a = \frac{1}{2} \eta_{BC} e_{\mu} e_{\nu} B_{\lambda\rho}^C \). Then we have the Einstein action. In the process of solving the constraint the extra Kalb-Ramond symmetry possessed by the topological "BF" theory is broken in an ad hoc way. Instead we wish to start with the Kalb-Ramond invariant action and derive the constraint spontaneously. The Kalb-Ramond symmetry, \( B_{\mu\nu}^a \rightarrow B_{\mu\nu}^a + \nabla_{\mu}^a \Lambda_{\nu}^b - \nabla_{\nu}^a \Lambda_{\mu}^b \), was originally the gauge symmetry of strings. Therefore, by introducing the string field, we write down the following Kalb-Ramond invariant action:

\[
S = \int d^4 x \frac{1}{2} \epsilon^{\mu\nu\lambda\rho} B_{\mu\nu}^a(x) R_{\lambda\rho}^a(x)
+ \sum_C \sum_{x_0(\in C)} \sum_{x(\in C)} \epsilon^{\mu\nu\lambda\rho} \left[ \left( \frac{\delta}{\delta C_{\mu\nu}^a(x)} + T^a B_{\mu\nu}^a[C; x, x_0] \right) \Psi[C; x_0] \right]^\dagger \times \left[ \left( \frac{\delta}{\delta C_{\lambda\rho}^a(x)} + T^a B_{\lambda\rho}^a[C; x, x_0] \right) \Psi[C; x_0] \right]
\]
\[ + \sum_{C} \sum_{x_0} V[\Psi[C; x_0]|\Psi[C; x_0]]. \]  

(2)

In this expression we need to modify the Kalb-Ramond field \( B_{\mu\nu}^a \) and its transformation to the non-local ones, reflecting the difficulty of their non-Abelian versions. Now the condensation of the string fields

\[ \frac{1}{2} \phi^{ab}[C; x_0] \equiv \langle \Psi[C; x_0]|T^a T^b \Psi[C; x_0] \rangle, \]  

(3)

plays the role of the Lagrange multiplier. If the condensation becomes large for the symmetric (isospin 2) part of \((a, b)\), then its coefficient gives the constraint, leading to the Einstein gravity. For the details refer to Ref. [4].

3 Phase Transition Dynamics and Field Theory of Membranes

During the temporal development of the 1st order phase transition, like the cooling down of the vapor (unbroken phase), liquid droplets of water (bubbles of the broken phase) are nucleated, they fuse with themselves, and finally the whole vessel (the whole space) is filled up with the water (broken phase). It is really amazing to know that for such a difficult problem there exists a solvable theory called the Kolmogorov-Avrami theory [11], if the critical radius of the bubble is vanishing and the wall velocity is constant. "Solvable" means that we can exactly know the probability of the arbitrarily chosen \(N\) spacetime points to belong to the broken or the unbroken phase. This may suggest the existence of a solvable non-relativistic membranic (interfacial) field theory. It is another Kikkawa-type physics to pursue.

References

[1] A. Sugamoto, Phys. Rev. D19 (1979) 1820; K. Seo, M. Okawa, and A. Sugamoto, Phys. Rev. D19 (1979) 3744; K. Seo and M. Okawa, Phys. Rev. D21 (1980) 1614; K. Seo and A. Sugamoto, Phys. Rev. D24 (1981) 1630.

[2] A. Sugamoto, Nucl. Phys. B215 (1983) 381.

[3] K. Kikkawa and M. Yamasaki, Prog.Theor. Phys. 76 (1986) 1379.

[4] M. Katsuki, H. Kubotani, A. Sugamoto and S. Nojiri, Mod. Phys. Lett. A29 (1995) 2143; M. Katsuki, S. Nojiri, and A. Sugamoto, OCHA-PP-61, NDA-PP-20 (1995), to be published in Int. J. Mod. Phys. A.
[5] M. Kawamura, A. Sugamoto and S. Nojiri, Mod. Phys. Lett. A9 (1994) 1159 ; S. Nojiri, M. Kawamura and A. Sugamoto, Phys. Lett. B343 (1995) 181 ; S. Nojiri, M. Kawamura and A. Sugamoto, preprint, NDA-FP-21, OCHA-PP-65 (1995), to be published in Mod. Phys. Lett. A ; E. Elizalde, S. D. Odintsov, S. Nojiri, M. Kawamura and A. Sugamoto, preprint, UB-ECM-PF 95/9-13, NDA-FP-22, OCHA-PP-66 (1995) hep-th/9511167; M. Kawamura, preprint, OCHA-PP-71, hep-th/9601156.

[6] I. Senda and A. Sugamoto, Nucl. Phys. B302 (1988) 291 ; Phys. Lett. 209B (1988) 221 ; Phys. Lett. 211B (1988) 308 .

[7] M. Marui, I. Oda and A. Sugamoto, Int. J. Mod. Phys. A5 (1990) 4257.

[8] I. Oda and A. Sugamoto, Phys. Lett. B266, (1991) 280 ; A. Nakamichi, I. Oda and A. Sugamoto, Phys. Rev. D44 (1991) 3835 ; F. Nagamori, A. Sugamoto and I. Oda, Prog. Theor. Phys. 88 (1992) 797.

[9] S. Kokubo and A. Sugamoto, Computer Phys. Comm. 75 (1993) 311 .

[10] A. Sugamoto, in the "Proc. of the Trieste Conference on Supermembranes and Physics in 2+1 Dimensions, M. J. Duff, C. N. Pope, and E. Sezgin (Eds.), World Scientific, pp16-28, (1990).

[11] A. N. Kolmogorov, Bull. Acad. Sci. U.S.S.R. , Phys. Ser. 3 (1937) 335 ; M. J. Avrami, Chem. Phys. 7 (1939) 1103 ; S. Ohta, T. Ohta, and K. Kawasaki, Physica A140 (1987) 478 .