International workshop on

SUPERSTRINGS, COSMOLOGY COMPOSITE STRUCTURES

53.533C53
I 61.4
1987

International workshop on

SUPERSTRINGS, COSMOLOGY COMPOSITE STRUCTURES

March 11-18, 1987
Center for Theoretical Physics
University of Maryland at College Park

Editors:
S. J. Gates, Jr.
R.N. Mohapatra

World Scientific
Singapore • New Jersey • Hong Kong

Published by

World Scientific Publishing Co. Pte. Ltd.
P.O. Box 128, Farrer Road, Singapore 9128

U. S. A. office: World Scientific Publishing Co., Inc.
687 Hartwell Street, Teaneck NJ 07666, USA

Library of Congress Cataloging-in-Publication Data

International Workshop on Superstrings, Composite Structures, and Cosmology (1987 : College Park, Md.)
Superstrings, composite structures, and cosmology : proceedings of the International Workshop on Superstrings, Composite Structures, and Cosmology, College Park, Maryland, 11–18 March, 1987 / edited by S. Gates Jr. & R. N. Mohapatra.
p. cm.
ISBN 9971503735. ISBN 9971503840 (pbk.)
1. Superstring theories –– Congresses. 2. String models –– Congresses. 3. Cosmology –– Congresses. I. Gates, S. James. II. Mohapatra, R. N. (Rabindra Nath) III. Title.
QC794.6.S85I58 1987 530.1'42 –– dc19 87–27993

SUPERSTRINGS, COSMOLOGY AND COMPOSITE STRUCTURES

Copyright © 1987 by World Scientific Publishing Co Pte Ltd.

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

ISBN 9971-50-373-5

Printed in Singapore by Kim Hup Lee Printing Co. Pte. Ltd.

PREFACE

Superstrings have created a sensation in theoretical particle physics during the past several years. For the first time in history, there is a class of theories which raise the possibility of unifying all of the four forces of nature — gravitational, weak, electromagnetism, and strong — into a single consistent mathematical framework. This would be the realization of the dream of Einstein to create a "unified field theory."

There is also a kind of uniqueness about string theories that was missing in prior theoretical developments in particle physics, including grand unified theories, supersymmetry and supergravity, and Kaluza-Klein methods. As such, the superstring theories have elevated the program of unification in fundamental physics to new heights. At the root of these developments is a radical new concept that the ultimate structure of matter consists not of point particles, as was conventionally thought, but of extended one dimensional objects — the strings or superstrings. The "stringy" structure is presumed to manifest itself at length scales corresponding to the Planck length, of order 10^{-33} centimeters, and thus a whole new picture of the universe prior to the Planck time ($\approx 10^{-44}$ seconds) is suggested. This may shed new light on such fundamental questions as to the origin of time and space. Although the development of the field has been explosive, we are still just at the beginning of an understanding of these theories. An example of this is the fact that only within the last year has it been realized that string theories can "comfortably" exist in a world of four spacetime dimensions. A particularly intriguing development is the interplay between superstring theories and certain branches of mathematics. Another is the growing connection between cosmology and particle physics.

It was with a view to capturing these exciting developments that we, at the University of Maryland, decided to organize a workshop on the subject. Many leading experts working in different aspects of string theories participated in the workshop and presented their latest results. The conference ran for a week. Each full day of seminars was followed by an evening discussion session. The lectures not only focused on formal developments but also explored to what extent these theories can describe known quark-lepton interactions at low energies. In addition, there was considerable discussion of related areas such as dynamical symmetry breaking, compositeness and cosmology as well as of certain aspects of mathematics. Nature cooperated by revealing the explosion of the supernova SN 1987A in time for this important event to be presented at our meeting.

Our most sincere thanks go to all of the speakers for contributing to what was an exciting meeting. In the following, we have compiled as many talks as possible to provide a record of the meeting. It is our hope that this effort will prove valuable to the community at large by providing a convenient reference for the recent developments in a frontier field.

The workshop on Superstrings, Composite Structures and Cosmology is part of a special year program which was initiated following a generous grant given by the Center For Theoretical Physics of the University of Maryland. On the basis of this grant we applied to other sources. Major help came from the Graduate School of the University of Maryland, which, to our delight, decided to support this special year program despite competition from many other proposals. A generous grant from the National Science Foundation for holding the workshop was also very helpful. On behalf of our colleagues and students, we would like to thank these sources for financial support. We are especially grateful to the chairman of our department, Professor C. S. Liu, who gave us constant encouragement during the organization of the Special Year Program.

We thank our secretaries Betty Krusberg, Connie Rich and Susan Farris for their great help in the organization of the workshop. We want to mention the help which we received from our students — Balakrishnan, Sekyu Chang, Tristan Hübsch, Alok Kumar, Alexander Mikovic, Pramoda Mohapatra and Robert Oerter. We further wish to thank the members of the international advisory committee: D. J. Gross, B. Sakita, A. Salam, J. H. Schwarz, Q. Shafi, P van Nieuwenhuizen, and S. Wadia for their support and advice. Finally we acknowledge the help of the other members of the local organizing committee; P. Green, Y. S. Kim, C. R. Preitschopf, W. Siegel, and A. E. van de Ven. Without their assistance, it would not have been possible to organize this workshop.

Editors

S. J. Gates, Jr.
R. N. Mohapatra

Chairman

J. C. Pati

此为试读，需要完整PDF请访问：www.ertongbook.com

CONTENTS

Cosmology and Phenomenology

Composite Structures

String Field Theory

此为试读，需要完整PDF请访问：www.ertongbook.com

CONTACT INTERACTIONS OF CLOSED SUPERSTRINGS *

J. Greensite

Physics and Astronomy Dept.
San Francisco State University
San Francisco, CA 94132

ABSTRACT

It is shown that closed light-cone superstring field theory, which is presently formulated with only cubic interaction terms, does not have a stable ground state, and that the global supersymmetry algebra is violated at second order in the coupling. Local contact interactions, of quartic (and possibly higher) order in the string fields, must be added to the light-cone Hamiltonian to restore supersymmetry and vacuum stability.

There has been a great deal of progress over the past two years in developing a covariant formulation of string field theory, and at the moment there are at least two approaches which appear promising [1,2]. Very much less attention has been devoted to the original light-cone formulation; the general belief is that on the light-cone at least, both the bosonic string and superstring field theories are known in their entirety. In this talk I will dispute this general belief, as it applies to superstrings, and argue that light-cone superstring field theory contains new quartic contact terms which have no analogue in the bosonic string field theory. The work reported here was done in collaboration with Frans Klinkhamer.

Closed superstring field theory, as presently formulated, is a kind of generalized ϕ^3 theory. The light-cone gauge Hamiltonian of the Type IIB

---

* Talk presented at the International Workshop on Superstrings, Composite Stuctures, and Cosmology, Univ. of Maryland, March 11-18 1987.

theory, for example, is given by [3]

$$H = \int d\alpha\, \alpha \int D^{16}z\ \Psi_{-\alpha}[z(\sigma)]\ h_2\ \Psi_{\alpha}[z(\sigma)]$$
$$+ \lambda \int \prod_{r=1}^{3} d\alpha_r\, D^{16}z_r\ \delta(\textstyle\sum \alpha_r)\ \delta[z_1(\sigma)+z_2(\sigma)-z_3(\sigma)]\ h_3\ \Psi[1]\,\Psi[2]\,\Psi[3] \qquad (1)$$

where $\alpha=2p_+$ is the light-cone string-length, $z(\sigma)=\{x(\sigma),\theta^A(\sigma),\tilde{\theta}^A(\sigma)\}$ are the string coordinates, and Ψ is the string-field operator with commutation relations

$$[\Psi_\alpha[1],\Psi_\beta[2]] = \alpha^{-1}\,\delta(\alpha+\beta)\int(d\sigma_0/\pi|\alpha|)\ \delta[z_1(\sigma)-z_2(\sigma+\sigma_0)] \quad . \qquad (2)$$

h_2 is the hamiltonian of the 1st-quantized string theory, and h_3 is a local operator, composed of the superstring coordinates $z(\sigma)$ and their conjugate momenta, defined at the interaction point where one string splits into two strings, or two strings join to form a single string.

Does this Hamiltonian have a ground state? It is well known that ordinary point-field ϕ^3 theory does not have a stable vacuum. However, superstring field theory should satisfy a global supersymmetry algebra, and this algebra must guarantee that the light-cone Hamiltonian is positive semi-definite. The energy of a supersymmetric string theory is therefore bounded from below, and a ground state must exist. But this argument can be turned around. If negative-energy string field states can be constructed, then the cubic Hamiltonian above is not supersymmetric as it stands.

As a warm-up exercise, let us consider the instability of point-field ϕ^3 theory quantized in the light-cone frame. The Hamiltonian in l.c. coordinates is

$$H = \int d\alpha \int d^{D-2}x\, [\nabla\phi_\alpha^\dagger\cdot\nabla\phi_\alpha + m^2\,\phi_\alpha^\dagger\phi_\alpha\,] \ +$$
$$\lambda\int d\alpha_1 d\alpha_2 d\alpha_3 \int d^{D-2}x\,[\phi_{\alpha_3}^\dagger\phi_{\alpha_2}\phi_{\alpha_1} + \phi_{\alpha_1}^\dagger\phi_{\alpha_2}^\dagger\phi_{\alpha_3}]\ \delta(\alpha_1+\alpha_2-\alpha_3)\ , \qquad (3)$$

with

$$[\,\phi_\alpha(x), \phi_\beta^\dagger(y)] = \alpha^{-1}\,\delta(\alpha-\beta)\ \delta^{D-2}(x-y) \quad . \qquad (4)$$

In the l.c. frame, the perturbative ground state $|0\rangle$ (defined by $\phi_\alpha|0\rangle=0$) is also an exact eigenstate of the full interacting theory, since $H|0\rangle = 0$. This fact is just a peculiarity of quantization in light-cone coordinates.

However, light-cone quantization is not a cure for the well-known instability of this theory, and therefore the perturbative state $|0\rangle$ is <u>not</u> the true ground state. To see this, consider the trial state

$$|f\rangle = \exp[\, \beta \int dx \int d\alpha\, \alpha\, f_\alpha(x)\, \phi_{-\alpha}(x)\,]\; |0\rangle \tag{5}$$

The energy expectation value of this state is

$$E_f(\beta) = \frac{\langle f|H|f\rangle}{\langle f|f\rangle}$$

$$= \beta^2 \int d\alpha \int d^{D-2}x\, [\, \nabla f_\alpha^{*} \cdot \nabla f_\alpha + m^2 f_\alpha^{*} f_\alpha\,]$$

$$+ \beta^3 \lambda \int d\alpha_1\, d\alpha_2\, d\alpha_3 \int d^{D-2}x\, [f_{\alpha_3}^{*} f_{\alpha_2} f_{\alpha_1} + \text{c.c}]\, \delta(\alpha_1+\alpha_2-\alpha_3)\ , \tag{6}$$

If we choose, e.g.

$$f_\alpha(\vec{x}) = \exp(-\vec{x}^2 - \alpha^2) \tag{7}$$

then

$$E_f(\beta) = \beta^2 \times (\text{finite const.}) + \beta^3 \times (\text{finite const.})$$
$$\to -\infty \qquad \text{as} \qquad \beta \to -\infty \tag{8}$$

which just shows that point-field ϕ^3 theory is as unstable in light-cone coordinates as in any other system of coordinates.

The same logic can be used to demonstrate the vacuum instability of the type IIB Hamiltonian above. The strategy is simply to condense a finite number of string-field modes, which then leads to an expression for the energy which is similar to the point-field ϕ^3 case. Consider, for example, the trial string-field state

$$||F\rangle\rangle = \exp[\, \beta \int_0^\infty d\alpha\, \alpha \int d^8p\, d^4\theta\, d^4\tilde{\theta}\;\; F_\alpha(p\theta\tilde{\theta})\, \Psi_{-\alpha}{}^{00}(p\theta\tilde{\theta})\,]\; ||0\rangle\rangle\ , \tag{9}$$

where

$$F_\alpha(p,\theta,\tilde{\theta}) = f_\alpha(p)\, (\theta^{\bar{1}}\theta^{\bar{2}}\theta^{\bar{3}}\theta^{\bar{4}} + \tilde{\theta}^{\bar{1}}\tilde{\theta}^{\bar{2}}\tilde{\theta}^{\bar{3}}\tilde{\theta}^{\bar{4}}\,)\ , \tag{10}$$

and $\Psi_{-\alpha}^{\infty}$ is the superfield creation operator of massless closed superstrings. After some Grassman integrations, the energy expectation value of this state is

$$E_F(\beta) = \langle\langle F|| H ||F\rangle\rangle / \langle\langle F||F\rangle\rangle$$

$$= 2\beta^2 \int d\alpha \int d^8p \; f_\alpha^*(p)\, p^2\, f_\alpha(p)$$

$$+ \beta^3 \lambda \int d\mu_{3B} \{2|\alpha_1\alpha_2\alpha_3|^{-3} (\alpha_1^4+\alpha_2^4+\alpha_3^4) \exp(-\tau_0 P^2/\alpha)$$

$$\cdot P^L P^R (f_{\alpha_1}^*(p_1)\, f^*_{\alpha_2}(p_2)\, f_{\alpha_3}(p_3) + c.c.) \} \quad , \qquad (11)$$

where

$$P = (\alpha_1 p_2 - \alpha_2 p_1)/2 \,,$$
$$\tau_0/\alpha = [\alpha_1 \ln|\alpha_1| + \alpha_2 \ln|\alpha_2| + \alpha_3 \ln|\alpha_3|] / (\alpha_1\alpha_2\alpha_3) > 0 \,,$$
$$P^L P^R = (P_7^2 + P_8^2) > 0 \,. \qquad (12)$$

Again, for some simple choice of $f_\alpha(p)$, e.g. $f_\alpha(p) = \exp(-\vec{p}^2-\alpha^2-\alpha^{-2})$, we find

$$E_F(\beta) = \beta^2 \times (\text{finite const.}) + \lambda\, \beta^3 \times (\text{finite const.})$$
$$\rightarrow -\infty \quad \text{as} \quad \beta \rightarrow -\infty \quad . \qquad (13)$$

The conclusion is that the energy spectrum of the theory described by eq. (1) is unbounded from below, which means that the l.c. Hamiltonian containing only cubic interaction terms cannot be supersymmetric. There must then be some loophole in the arguments which claim that it is supersymmetric.

Superstring field theory is required to satisfy a global super-Poincare algebra, which includes anticommutation relations of the form

$$\{Q^{-A}, Q^{-\bar{B}}\} = 2\, H\, \delta^{A\bar{B}}, \qquad \{Q^{-A}, Q^{-B}\} = \{Q^{-\bar{A}}, Q^{-\bar{B}}\} = 0 \;, \qquad (14)$$

where the A, $\bar{A}$ indices refer to 4 and $\bar{4}$ representations of SU(4). Green and Schwarz in ref. [3] constructed supercharges $Q^{-A,\bar{A}} = Q_2^{-A,\bar{A}} + \lambda Q_3^{-A,\bar{A}}$ (where subscripts 2,3 refer to terms quadratic and cubic in the string fields), which together with the Hamiltonian of eq. (1) satisfy the super-Poincare relations (14) to $O(\lambda)$. They also argued that these relations are actually satisfied exactly, i.e. $\{Q_3^-, Q_3^-\} = 0$. Their argument goes as follows: The interaction part of the supercharge, Q_3^- can be represented schematically by

$$Q^- = \langle 123|Q\rangle \Psi_3^\dagger \Psi_2 \Psi_1 \quad + \quad \langle 123|Q\rangle \Psi_1^\dagger \Psi_2^\dagger \Psi_3$$

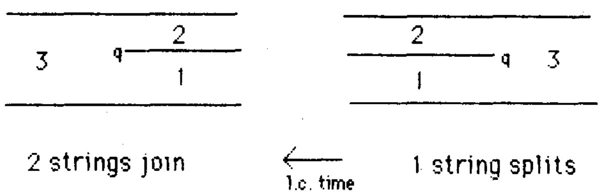
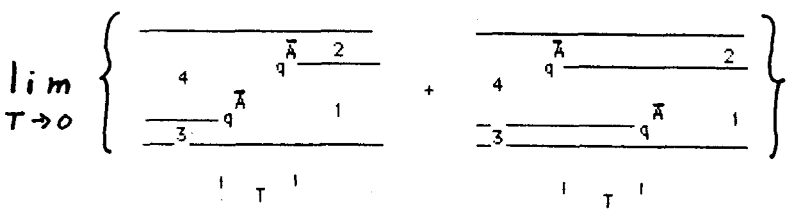


Fig. 1

Contributions to, e.g., $Q^{-\bar{A}}\, Q^{-\bar{A}}$ sandwiched between 2-string states, i.e. $M = \langle\langle 34 \| Q^{-\bar{A}}\, Q^{-\bar{A}} \| 12 \rangle\rangle$, can be represented by l.c. diagrams



+ (s-t, t-u channel diagrams)

Fig. 2

However, the two diagrams shown above differ, in the T→0 limit, only in the order of the local $q^{\bar{A}}$ operators. Because these operators at different interaction points anticommute, the two diagrams shown above cancel exactly.

The loophole in this cancellation argument, for general values of p^+, is that it neglects contributions in which the interaction points coincide. For open strings, these contributions are the non-planar diagrams (again in the T→0 limit)

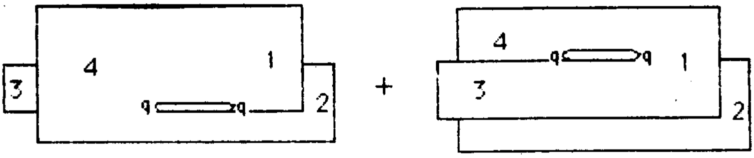


Fig. 3

These diagrams are non-vanishing (in fact they are divergent in the T→0 limit), and do not cancel in general. A detailed discussion of the open-string case may be found in ref. [4].*

For closed strings, all diagrams contributing to M=<<34|{Q⁻,Q⁻}|12>> contain contributions where the interaction points coincide. For example, the closed-string s-channel diagram

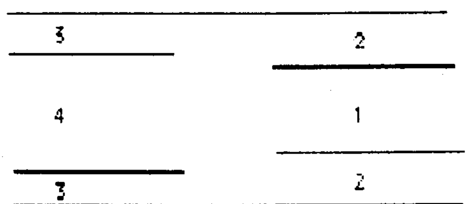


Fig. 4

contains an integration over the relative location of the join/split interaction

* Green and Schwarz in ref. [3] have noted that the cancellation argument could break down in the planar s-t channel, for the special case that $\alpha_1=\alpha_4$. This is the one case in the s-t channel where the interaction points can coincide. It was also argued in [3] that the resulting interaction term is in the purely forward direction. Our discussion, however, shows that there are non-cancelling contributions to the anticommutators for arbitrary values of string length α; moreover, we do not agree that the special s-t term is in the purely forward direction (cf. ref.[4]).

此为试读,需要完整PDF请访问: www.ertongbook.com