I. INTRODUCTION

This is a time of considerable change in the Yale theoretical high energy group. Our distinguished colleague Feza Gursey, the J.W. Gibbs Professor of Physics at Yale, will retire on July 1, 1991 after 25 years on the faculty. He plans to continue his active research career, including an ongoing collaboration with members of our nuclear theory group, dividing his time between New Haven and Turkey. Feza is a great scientist and a great source of wisdom and inspiration for all of us. We look forward to seeing much of him in the years ahead.

We are very fortunate to have attracted Gregory Moore here as a tenured Associate Professor in 1989. He received a Presidential Young Investigator award last year, is now well settled in, and is beginning to build a group with strong ties to our condensed matter theorists and to the excellent mathematical physics group in the Yale Mathematics Department. One associate research physicist (postdoctoral fellow), Cedomir Crnkovic, has been supported by university start-up funds in connection with Greg's appointment. In September, 1991, he will be replaced by M. Ronen Plesser who will be supported by funds from Greg's PYI award.

A key new faculty appointment in this general area is that of Hubert Saleur. He joined us in January, 1991 from the Service de Physique Theorique, Saclay, France, as a term Associate Professor.

Another very important recent development is the appointment of William Marciano as Adjunct Professor of Physics at Yale. Bill now visits regularly from Brookhaven Laboratory, teaches a graduate seminar course, interacts with all of us, and is already guiding the research of one of our graduate students.

During the 1990/91 academic year, four members of our group (Appelquist, Krauss, Marciano and Soldate) received a grant from the Texas National Research Laboratory Commission. Their's was one of a very small number of theoretical proposals chosen for funding within the new research and development program of the TNRLC. The initial funding year is April 1, 1991 to March 31, 1992. It is hoped that it will be renewed for at least the five year period covered by the proposal. This grant has allowed the group to appoint an additional associate research physicist, Soo-Jong Rey, who will join the group on September 1, 1991 and to support SSC-related research in a variety of ways. The TNRLC support is described in more detail in section III.

Two additional associate research physicists will continue as members of the group through the 1991/92 academic year. They are Evalyn Gates, who is supported by DOE funds, and John Terning, who is supported by a Canadian Postdoctoral Fellowship.

During the 1991/92 acdemic year, the theoretical group as a whole will consist of four tenured faculty members (Appelquist, Moore, Sommerfield, MacDowell), one emeritus professor (Gursey), one adjunct professor (Marciano), three non-tenured faculty members (Krauss, Saleur Soldate), one senior research physicist (Chodos), and four associate research physicists (Gates, Plesser, Rey, Terning). Only one of the associate research physicists (Evalyn Gates through September 1, 1991) will receive salary support from the DOE.

Interactions with other Yale physicists are strong. In the Physics Department, there is close contact, including collaboration, with Vincent Moncrief in gravitation physics and with Yoram Alhassid and Franco Iachello in nuclear theory. In the Mathematics Department, Igor Frenkel, Howard Garland, Gregg Zuckerman, and Louis Crane interact frequently with many of us, especially Feza Gursey and Greg Moore. Lawrence Krauss, who has a joint appointment in the Astronomy Department continues to interact regularly with people there and to collaborate with Pierre Demarque. One of the most important contacts we now have is with members of Yale's excellent theoretical condensed matter group consisting of R. Shankar, Doug Stone, Subir Sachdev, Nicholas Read, and Karin Rabe. Finally, interaction with the experimental high energy physicists in the Physics Department, in particular Charles Baltay and his group, have become very strong during the past year. We now hold a regular joint weekly seminar, funded partly by the new TNRLC grant.

The general level of research productivity in the group is very high and much of our work continues to have considerable impact in the field. Many of us are also actively involved in many other ways in the international physics community.

II. COMPOSITION OF THE GROUP

Principal Investigator:	Thomas Appelquist	
Faculty:	Feza Gürsey Lawrence Krauss Samuel MacDowell Gregory Moore Hubert Saleur Mark Soldate Charles Sommerfield	
Adjunct Professor:	William Marciano (Brookhaven National Laboratory)	
Research Personnel:	Alan Chodos	(partial salary support from Yale University)
	Cedomir Crnkovic	(salary support from Yale University, leaving September 1991)
	Evalyn Gates	
	M. Ronen Plesser	(salary support from the National Science Foundation, arriving July 1991)
	Soo-Jong Rey	(salary support from the Texas National Research Laboratory Commission; arriving in September 1991)
	John Terning	(salary support from a Canadian Postdoctoral Fellowship)
Research Students:	Hagai Attias	
	Wenxin Jiang	
	Wai Ming Koo	
	Sanjaye Ramgoolam	University support
	N. Ola Tornkvist	
	George Triantaphyllou	Partial TNRLC support
	Martin White	TNRLC support
	Guohong Wu	University support
Visitors:	Daniel Altschuler Andre Leonidov Vladimir Miransky David Owen	

RECENT AND PROPOSED RESEARCH OF FEZA GÜRSEY

F. Gürsey, with his collaborators and students has concentrated his research activities on the following areas:

I. Symmetries of Superstrings and Division Algebras.

It was shown in papers 2, 6, and 8 of Gürsey's publication list that the critical dimensions of supersymmetric Field Theories and Superstrings (D=3,4,6,10) are intimately related to the four division algebras through a new representation of the Super Poincare group by means of real and complex numbers, quaternions and octonions. Furthermore, compactification of extra dimensions was shown to arise by means of integer valued Jordan algebras which are linked to the division algebra representation of the Super Poincare group. This insight paves the way to the unification of the known superstring theories by imbedding them in an infinite Lie algebra (the Conway-Sloane algebra) related to the exceptional Jordan algebra through its root system. The aim is to obtain the various superstring theories by different modes of breaking the Conway-Sloane symmetry.

II. Four-dimensional generalizations of Conformal Field Theories (with W. Jiang).

There has been recent work on possible correspondence between 2-dimensional conformal field theories and 4-dimensional self-dual gauge theories and gravitation theories.[1] The relation established is through twistors and CP_3 projective geometry. In papers 14 and 15 of Gürsey's publication list, an alternative approach is developed through the quaternionic twistor representation of SL(2,H), the conformal group of euclidean space-time and homogeneous functions of the quaternionic twistor which lead to the projective geometry HP(1) and analytic functions of quaternions. The self-dual and anti-self-dual sectors are separated automatically corresponding to analytic and anti-analytic function in D=2. The generalization of the Virasoro algebra is shown to be the infinite quasi-conformal algebra of the generators of quaternion analytic (Fueter) functions. This algebra admits the conformal algebra SO(5,1) as a subalgebra in the same way that the double Virasoro algebra of D=2 conformal transformations admits SO(2,2) ~ SL(2,R) x SL(2,R) as a subalgebra generating the Möbius transformations. The quasi-conformal algebra is also shown to leave Schwarzschild-type metrics form invariant. Operator extensions of infinite algebras in space-time are also discussed in paper 14. The aim is to generate 4-dimensional field theories that are covariant under the quasi-conformal group and to classify such theories through the representations of that infinite group.

Finally the quasi-conformal group in (2+2) dimensional space-time admits 0(2,2) as a subgroup, so that the function theory of 2x2 real matrices becomes related to recent work of Ooguri and Vafa[2] on self duality and N=2 supersymmetry.

III. QCD-Inspired Effective Lagrangians

Papers 1, 3, 4, 9, 10, 13, and 16 of Gürsey's publication list are devoted to various effective theories obtained from different approximations to the QCD theory of quarks and gluons. The main new result is the existence of an effective hadronic supersymmetry SU(6/21) between quarks and anti-diquarks in QCD based on SU(3). This leads to parallel Regge trajectories for baryons and mesons and to new mass formulae. It is also argued that the Skyrmion version of effective theories should be based on the same symmetry governing that the quark model. Generalizations of the Skyrme model along that line are shown to give better agreement with experiments. A recently proposed extension of the Skyrme model[3] is also improved upon in paper 13.

IV. Non-Commutative Geometry and the Standard Model

A. Connes[4] has proposed a method based on his non-commutative geometry for obtaining new relations among the parameters of the standard model. A flurry of activity[5] has followed the publication of Connes' ideas. Those papers are classical so that what happens to the relations obtained after renormalization of the quantum version is not discussed. In paper 11 two new ideas were introduced. First, the non-commutative geometry as far as it is relevant to the standard model was related to familiar BRST techniques and 1-forms and 2-forms were obtained through the superfield formalism using the superconstraint algebra.[6] Secondly the renormalization group was used to derive the change in relations obtained from non-commutative geometry assuming the symmetry to be valid at a high mass scale. A simple example is given in paper 11 which is more realistic than previous examples. This work is in collaboration with Balakrishna and Wali.

V. Group Theoretical Approach to Scattering (with Iachello, Alhassid and Wu).

Group theoretical techniques introduced previously for dealing with scattering problems[7] were generalized to the the group SO(2,2) in paper 7 of Gürsey's publication list and to the relativistic case in paper 5 in which the new concept of linear Casimir operators was introduced. The approach has potential applications to nuclear and molecular physics as well as particle physics.

Future Prospects

It is proposed to generalize the division algebra approach of part 1 to quantum strings and quantum algebras. In part 2, quaternion analyticity in both the euclidean and the (2+2) cases shows analogies with the Ashtekar variables in Quantum Gravity. A clarification of these relations will be attempted. Also the theory of functions of real 2x2 matrices will be applied to the N=2 superstring of Ooguri and Vafa. [18] Finally, Lagrangians exhibiting quasi-conformal invariance will be sought and discussed. In part 3 a supersymmetric extension of the Skyrme model is being developed. In part 4 more realistic models obtained from non-commutative geometry will be discussed and the method will be generalized to left-right symmetric theories and to standard models and GUT's including QCD. In part 5 it is proposed to generalize the group theory approach to Quantum Groups.

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