THE INSTITUTE OF MATHEMATICAL SCIENCES

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ANNUAL REPORT

April 1, 1996 – July 31, 1997

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FOREWORD

Beginning this year, we decided that the annual report describing the events of the Institute may cover the events of an academic year rather than the financial year. Hence this volume in your hand lists various activities of the Institute for the period April 1996 - July 1997; in subsequent years, the report will cover the period August-July.

The year saw many discussions on the proposals for the Ninth Five Year Plan of the nation that began in April 1997. The Institute hopes to create, during this plan period, additional space to house many of its increased level of activities and augment the necessary infrastructure. Special effort will be made to enhance our Library Complex, so that it is ready to take full advantage of the raging information revolution and the consequent profound changes that may be incorporated into the set up of the library of a research Institute during the 21st century. We also recognise the need to ensure that computing power of the Institute always remain adequate, and that timely investment is made to remain at the cutting edge of problem solving. Since the Institute is involved in basic research it is only natural for us to have active collaboration with the faculty and students of the Universities and thereby strengthen the knowledge base of our nation. In the next plan period we hope to enhance these opportunities by initiating specific programmes. The Institute is recognised as a Centre of Excellence by the Third World Academy of Sciences (Trieste), so that we may play the role of a resource centre in the south-south collaboration in the International scene. In this programme we plan to have about ten Associateships that will enable mathematicians and physicists working in "the third world" an opportunity to enhance their efforts through academic interaction with us.

The year under review saw our hosting two International gatherings : one on Operator Algebras and the other on Special functions & Differential Equations; as well as an Update Meeting on Timed Systems - details of which you will find in this report. In addition, we held pedagogically oriented Instructional Conference on Nonlinear Functional Analysis, the preliminary part of the 12th SERC School on High Energy Physics, and a Summer School on Introduction to Theoretical Aspects of Computer Science.

Among the laurels won by our academic staff, I would like to highlight that of V.S. Sunder. who won the coveted Shanti Swarup Bhatnagar Prize in Mathematics this year.

This Annual Report has been compiled through the efforts of a committee consisting of V.S. Sunder, R. Simon, Tapash Chakraborty, R. Jagannathan, Venkatesh Raman and K.S. Santhanagopalan; further G. Venkatesan provided the necessary support, and Usha Otheeswaran assisted in typesetting the annual report using LaTeX and to all of them I owe my gratitude.

We look forward to another year of exciting achievements of the Institute.

August 1997

R. Ramachandran
Director

Contents

1 The Institute **1**
- 1.1 Board . . . 1
- 1.2 Executive Council . . . 3
- 1.3 Faculty . . . 4
- 1.4 Post-Doctoral Fellows . . . 6
- 1.5 Ph.D. Students . . . 7
- 1.6 Administrative Staff . . . 9

2 Academic Activities **11**
- 2.1 Summary of research . . . 11
  - 2.1.1 Mathematics . . . 11
  - 2.1.2 Physics . . . 16
  - 2.1.3 Theoretical Computer Science . . . 28
- 2.2 Publications . . . 31
  - 2.2.1 Mathematics . . . 31
  - 2.2.2 Physics . . . 35
  - 2.2.3 Theoretical Computer Science . . . 48
  - 2.2.4 Books authored/edited/etc. . . . 51
- 2.3 Conferences/Workshops held at IMSc . . . 52
  - 2.3.1 International Conference on Operator Algebras . . . 52
  - 2.3.2 Workshop on Special Functions & Differential Equations . . . 54
  - 2.3.3 Instructional Conference On Nonlinear Functional Analysis . . . 57
  - 2.3.4 Symposium on Neurosciences . . . 58
  - 2.3.5 Update Meeting on Timed Systems . . . 58
- 2.4 Seminars . . . 60
- 2.5 Visitors . . . 74
- 2.6 Student Programme . . . 83
  - 2.6.1 Institute JRFs . . . 83
  - 2.6.2 Summer Students . . . 86
  - 2.6.3 NURTURE Programme . . . 87
  - 2.6.4 Summer School in TCS . . . 89
  - 2.6.5 XII SERC School on High Energy Physics: Part I . . . 90
  - 2.6.6 The National Science Day . . . 90
  - 2.6.7 The M.T. & T.S. Programme . . . 91

2.7 Visits to other Institutions 92
2.8 Other Professional Activities 115
2.9 Honours and Awards 118

3 Computer Facilities **119**

4 The Library **121**

Chapter 1

The Institute

1.1 Board

Thiru **K. Anbazhagan**, Minister for Education, Government of Tamil Nadu, Madras
(**Chairman**)

Dr. **R. Chidambaram**, Chairman, Atomic Energy Commission and Secretary to Government of India, Department of Atomic Energy, Bombay
(**Vice Chairman**)

Prof. **M. Anandakrishnan**, Vice Chancellor, Anna University, Madras
(**Member**) (upto Aug. 96)

Prof. **R.M. Vasagam**, Vice Chancellor, Anna University, Madras
(**Member**) (from Sep. 96)

Prof. **C.K. Majumdar**, Director, S.N.Bose National Center for Basic Sciences, Calcutta
(**Member**)

Prof. **G. Rajasekaran**, Distinguished Professor, Institute of Mathematical Sciences, Madras
(**Member**)

Prof. **V.S.Ramamurthy**, Secretary, Department of Science and Technology, New Delhi,
(**Member**)

Prof. **K.R. Parthasarathy**, Distinguished Scientist, Indian Statistical Institute, Delhi Center, New Delhi
(**Member**)

Shri **B.K. Saha**, I.A.S., Joint Secretary to Government of India, Department of Atomic Energy, Bombay

(**Member**) (upto May 96)

Shri **A. Dasgupta**, I.A.S., Joint Secretary to Government of India, Department of Atomic Energy, Bombay
(**Member**) (from June 96)

Shri **L.N. Vijayaraghavan**, I.A.S., Secretary to Government, Education Science and Technology Department, Government of Tamil Nadu, Fort St. George, Madras
(**Member**) (upto Aug.96)

Shri **S.P. Elangovan**, I.A.S., Secretary to Government, Education Science and Technology Department, Government of Tamil Nadu, Fort St. George, Madras
(**Member**) (from Sep.96)

Prof. **R. Ramachandran**, Director, The Institute of Mathematical Sciences, Madras
(Member Secretary)

1.2 Executive Council

Dr. **R. Chidambaram**, Chairman, Atomic Energy Commission and Secretary to Government of India, Department of Atomic Energy, Bombay
(**Chairman**)

Prof. **K.R. Parthasarathy**, Distinguished Scientist, Indian Statistical Institute, New Delhi
(**Member**)

Prof.**V.S. Ramamurthy**, Secretary, Department of Science and Technology, New Delhi
(**Member**)

Prof. **G. Rajasekaran**, Distinguished Professor, Institute of Mathematical Sciences, Madras
(**Member**)

Shri **B.K.Saha**, I.A.S., Joint Secretary to Government of India, Department of Atomic Energy, Bombay
(**Member**) (upto May 96)

Shri **A. Dasgupta**, I.A.S., Joint Secretary to Government of India, Department of Atomic Energy, Bombay
(**Member**) (from June 96)

Shri **L.N. Vijayaraghavan**, I.A.S., Secretary to Government, Education Science and Technology Department, Government of Tamil Nadu, Fort St. George, Madras
(**Member**) (upto Aug.96))

Shri **S.P. Elangovan**, I.A.S., Secretary to Government, Education Science and Technology Department, Government of Tamil Nadu, Fort St. George, Madras
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Prof. **R. Ramachandran**, Director, Institute of Mathematical Sciences, Madras
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Krishna, M.	krishna	492 8499
Nag, S.	nag	
Nagaraj, D.S	dsn	
Paranjape, Kapil H	kapil	
Srinivas, K	srini	
Sunder, V.S	sunder	858 3343

PHYSICS

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Balakrishnan, Radha	radha	434 0102
Baskaran, G	baskaran	492 7304
Basu, Rahul	rahul	245 4794
Chakraborty, Tapash	tapash	
Date, G	shyam	245 6148
Govindarajan, T.R	trg	492 7309
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Jagannathan, R	jagan	401546
Jayaraman, T	jayaram	491 0580
Kaul, Romesh	kaul	413264
Majumdar, Parthasarathi	partha	413254

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Parthasarathy, R	sarathy	416146
Rajasekaran, G	graj	413395
Ramachandran, R (Director)	rr	442 0387
Rangarajan, S.K	skr	
Rao, Madan	madan	
Ray, Purusattam	ray	491 8212
Sathiapalan, Balachandran	bala	
Shankar, R	shankar	235 0436
Sharatchandra, H.S	sharat	418059
Simon, R.	simon	413270
Sinha, Rahul	sinha	
Sinha, Sudeshna	sudeshna	
Sridhar, R	sridhar	419145
Srinivasa Rao, K	rao	411347

THEORETICAL COMPUTER SCIENCE

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Kamal, Lodaya	kamal	
Mahajan, Meena	meena	413403
Raman, Venkatesh	vraman	245 2768
Ramanujam, R	jam	492 8138
Seth, Anil	seth	4927647

SCIENTIFIC OFFICER

G. Subramoniam	gsmoni	

1.4 Post-Doctoral Fellows

Name	*Userid*
MATHEMATICS	
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Chakraborthy, Kalyan	kalyan
Mohan, Radha	rmohan
PHYSICS	
Ramakrishna, S	ramki
Qureshi, Tabish*	tabish
Sa, Debanand*	debanand
Sengupta, Gautam	gautam
Sheshadri, K*	shesh
Sinha, Nita	nita
Sunil Kumar, P.B.*	sunil

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* *tenure at IMSc is over*

1.5 Ph.D. Students

Name	*Userid*
MATHEMATICS	
Bhattacharya, D.	dakshini
Rajesh, M	rajesh
Ramana, Surya	suri
Ravindra, G.V.	ravindra
Sabu, N	sabu
Srinivasan, R	vasanth
PHYSICS	
Adhikari, Ronojoy	adhikari
Arun, R.	arun
Babu, Dutta Sreedhar	sbdutta
Bal, Subrata.	subrata
Balaji, K.R.S.	balaji
Chaudhuri, Sarasij Ray	sarasij
Cheluvaraja, Srinath*	srinath
Das, Jayajit	jayajit
Das, Saurya	saurya
Dasgupta, Arundhati	dasgupta
Desikan, Shubashree*	shuba
Elizabeth, S.Mary*	mary
Khan, S.A	khan
Majumdar, Pushan	pushan
Manoj, G	manoj
Mishra, Anup Kumar	anup
Murugesh, S.	mgesh
Narayanan, Mohan	mohan
Ramadevi, P.*	rama
Sarkar, Tapobrata	sarkar
Sinha, Subhasis	subhasis
Varadarajan, Suneetha	suneeta
Vathsan, Radhika	radhika

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Mohalik, Swarup Kumar	swarup
Nagaraj, S.V	svn
Srinivasa Rao, S	ssrao
Vinodchandran, N.V	vinod

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* *tenure at IMSc is over*

1.6 Administrative Staff

Sethuraman, G.	Chief Administrative Officer
Jayaraman, R.	Administrative Officer
Krishnan, S.	Accounts Officer
Santhanagopalan, K.S.	Librarian

Amulraj, D.
Ashfack Ahmed, G.
Balakrishnan, A.R.
Balakrishnan, J.
Elumalai, G.
Ganapathi, R.
Gayatri, E.
Geetha, M.
Indra, R.
Janakiraman, J.
Moorthy, E.
Munuswami, N.
Munuswamy, M.
Muthukrishnan, M.
Muthusigamani, S.
Nithyanandam, G.
Parijatham, S.M.
Parthiban, V.
Radhakrishnan, M.G.
Rajasekaran, N.
Rajendran, C.
Ramesh, M.
Ravichandran, N.
Ravindran, A.
Rizwan Shariff, H.
Sampath, N.S.
Sankaran, K.P.
Selvaraj, M.
Tamil Mani, M.
Usha Devi, P.
Usha Otheeswaran
Vasudevan, T.V.
Varadaraj, M.
Venkatesan, G.
Venugopal, T.

Chapter 2

Academic Activities

2.1 Summary of research

2.1.1 Mathematics

Algebra

Some study was done on the relationships between different kinds of numerical invariants of integrally closed modules over two-dimensional regular local rings. For integrally closed ideals, many such relations follow from the so-called Hoskin-Deligne formula. An analogue of this formula for modules, was obtained, and this gives some interesting connections between the Buchsbaum-Rim multiplicity and length invariants. However, whether the 2-dimensional local Riemann-Roch formula follows from these relations is still unclear.

There has been some recent work on a question of Huneke and Srinivasan on bounds for the multiplicity of graded Cohen-Macaulay k-algebras. More precisely, let R be a polynomial ring in n variables and let I be a homogeneous ideal of R such that R/I is Cohen-Macaulay. Let m_i be the minimum of the shifts at the i-th place in the graded resolution of R/I and let M_i be the maximum of the shifts at the i-th place in a graded resolution of R/I and let p be the projective dimension of R/I. The conjecture says that the multiplicity of R/I is bounded below by $\frac{\prod m_i}{p}!$ and is bounded above by $\frac{\prod M_i}{p}!$ It has been shown that the lower bound holds in general, by reducing to the case of a lexicographic ideal and using results of Pardue on the bounds of Betti numbers of lexicographic ideals.

Algebraic Geometry

Some progress has been made on the Mathieu's Conjecture for reductive groups - which is known to imply the famous Jacobian Conjecture in Analysis. In particular, a reformulation has been found in the case of $G = SL(2)$.

Questions regarding compactifications of groups and their relationship with Geometric Invariant Theory have also been investigated.

There has been some progress ([M:NS])[1] in the search of a nice compactification of moduli

[1]These references are to the publication lists in §2.2; the first letter in these references is M,P or T, according as the referred paper occurs in §2.2.1, §2.2.2 or §2.2.3.

of vector bundles on a nodal curve so that when the nodal curve appears in a family of smooth curves as special fibre, the above compacification appears as a specialisation in the corresponding family of moduli spaces.

An analogue, for parabolic bundles, of the following result on ample vector bundles, has been obtained ([M:BiNr]): for a section of an ample vector bundle whose rank is less than the dimension of the base, the zero locus is nonempty and connected. Also some new examples of parabolic ample bundles have been constructed.

A new and simpler proof of the resolution of singularities has been recently given by F. Bogomolov and A. Pantev. This proof was studied and further simplifications were made in order to make the proof accessible to a person having a basic knowledge of Algebraic Geometry. (A paper ([M:P1]) detailing this is accepted for publication in the Proceedings of the European Conference on Algebraic Geometry, Warwick, 1996.)

Inspired by this proof, an attempt has been begun to understand and simplify the celebrated paper of H. Hironaka. This would also have implications towards understanding birational geometry, thus: a rational variety is unirational and thus rationally connected. Differentiating these classes of varieties (even for the case of hypersurfaces and complete intersections in projective space) is one of the tests of our understanding of the topology of algebraic varieties. In particular it is not known if all of these can co-exist in a connected family of varieties.

A number of boundary cases of interest were formulated with the idea of providing examples. It was felt that the method of Iskovskih-Manin could be applied to prove non-rationality in some cases. Towards this end, the resolution of singularities of rational maps has been studied. It is known that there is a divisor in the space of all cubics of dimension 4 which parametrises rational cubics. It has been proved that this is one of the boundary cases mentioned above.

A study has been made of the new invariants for 4-manifolds introduced by Seiberg and Witten. (A mathematical exposition of these invariants was presented at the conference on Topology and Geometry in the JNCASR-IISc in December.)

A study was made of the Analytic proof of the Morse inequalities due to E. Witten; and this proof was presented at the Instructional Conference on Non-Linear Functional Analysis at the IMSc.

Complex Analysis

Motivated directly by Polyakov string theory, a study was started, of the inverse system (tower) of all finite pointed coverings over a closed Riemann surface, X – and the concomitant Teichmüller theory. The direct limit, denoted $T_\infty(X)$, of the classical Teichmüller spaces was shown to carry on it the natural action of the universal commensurability modular group, $MC_\infty(X)$; that group has been demonstrated to be none other than the group of "virtual automorphisms" of the fundamental group of X.

Particular attention was given to the subgroup of the group $MC_\infty(X)$ that arises from the cofinal tower consisting of the "characteristic coverings" of X. The action of this subgroup on $T_\infty(X)$ allows us to descend to a direct limit of Riemann moduli spaces, and carry through ([M:BiN]) universal Polyakov measure constructions thereon.

The question arises as to the nature of these constructions when applied to a Riemann

surface X of finite conformal type – namely when we allow X to have finitely many punctures. That becomes of fundamental importance, and connects directly to arithmetic, when X is chosen to be the thrice punctured sphere: $X = \mathbf{CP^1} - \{0, 1, \infty\}$. The tower over this surface has been investigated, and elegant relationships have been found between various groups that are associated with this tower and its Teichmüller theory.

Some time was also spent in pursuing certain group theoretic aspects of the commensurability modular group constructions mentioned above. Further, certain crucial properties of the "geometrically induced subgroup" of that modular group (in the punctured case) were found.

Some rather simple formulae have been found – that can certainly be implemented in a computational package – to determine the variation of the uniformizing Fuchsian groups associated to a holomorphically varying family of algebraic curves (of fixed genus). These formulae for the change in the generators of the Fuchsian group are integral formulae with kernels involving some theta-type series.

Differential equations

Homogenization theory :

Work has been done ([M:KeSt]) on the homogenization of an optimal control problem governed by a second-order elliptic boundary value problem with a cost functional involving a Dirichlet type integral of the state variable.

There exists literature on the case where the coefficients of the differential operator and the cost functional were highly oscillatory, but periodic. The work under discussion studies the general (*i.e.* non-periodic) case; here, the investigation is extended to the next order of difficulty. In addition to oscillatory coefficients, it is assumed that the domain Ω is perforated. Thus for each value of the parameter ε, which tends to zero, the domain of the problem $\Omega_\varepsilon \subset \Omega$ also changes. The coefficients of the cost functional are computed under a technical condition which is automatically satisfied in the periodic case. A by-product of this analysis is a method for the computation of the limit of any quadratic form (with uniformly elliptic, oscillating coefficients) of the gradient of the solutions of a family of problems in classical homogenization. (Incidentally, the results in the periodic case have also been recovered by a different method, *viz.,* the method of multiple-scale convergence. Also, there has been progress, using this method, in the study of the optimal control problem, with Dirichlet boundary conditions on the holes.)

The mathematical justification of two-dimensional models for the eigenvalue problems in three-dimensional thin shell theories:

In recent years, a lot of work has been done on the mathematical justification of various classical two-dimensional models for the study of thin linearly elastic shells. For stationary problems, *i.e.* the study of the deformation of a shell under the action of body and/or surface forces, the shallow shell model (Ciarlet and Miara), the membrane shell model and Koiter's model (Ciarlet and Lods), and the flexural shell (Ciarlet, Lods and Miara), have been studied. Here, it has been proposed to study the case of vibrations of shells, *i.e.* the case of eigenvalue problems, and compare the models obtained with those of the stationary cases.

The study of the shallow shell has been completed ([M:KeSa]), and considerable progress has been made in the flexural shell case as well. The case of the membrane shell is also being studied; this introduces the need of new techniques to overcome the mathematical challenges posed by the problem.

In case of the shallow shell, there is an important difference between the model obtained by Ciarlet and Miara (for the stationary case) and the one under discussion (for the vibration case). In the former, the limiting problem is a system of coupled equations involving all the components of the limiting solution; in the latter, it is found that the limit is an elliptic fourth order eigenvalue problem involving only the vertical component of the limit eigenvector. Thus, it is possible to show that the shallow shell, in the limit, behaves in a fashion similar to a plate.

Mathematical Physics

Investigations into the inverse spectral theory of the Quantum Harmonic Oscillator have led to a new representation ([M:Kr]) of the Riemann zeta function, as a Fourier transform of an L^1 function. (The validity of this representation, can however, also be proved directly.) This representation naturally yields a reformulation of the Riemann hypothesis.

Some work was also done on the Calderon-Zygmund theory for the affine group, involving a study of the multiplier theory associated with what might be called the Affine Transform. This problem is hard since the natural left (or right) invariant measures on the affine group are not doubling. (For doubling measures a very general theory exists).

Further, some work was done on identifying the mobility edge, after proving the presence of pure point spectrum for a class of Anderson models with decaying randomness in higher dimension. (This is the first instance of rigorously identifying the mobility edge, and is being written.) In addition, there has been some progress in ongoing work on showing the existence of extended states for some other models.

Finally, there is continued work on the inverse spectral theory of the Harmonic Oscillator, with the main purpose of identifying the iso-spectral class of the Oscillator as a first step to understanding discrete spectra.

Number Theory

A famous conjecture by Graham says that if $a_1, a_2, \cdots, a_n$ is a set of n integers such that $a_1 < a_2 < \cdots < a_n$, then $max\ a_i/(a_i, a_j)$ is at least n. This conjecture, which was known for $n > 10^{60}$, has been proved ([M:BS]) for $n > 4$.

The following result was also obtained : Call a point(a, b) visible from a point (c, d) if the $gcd(a - c, b - d)$ is 1. One is interested in the set S of minimal cardinality such that any point (a, b) with $1 \leq a, b \leq n$ is visible from some point of S.It has been shown ([M:AB]) that such a set S exists with cardinality $\emptyset(logn\ logloglogn/loglogn)$.

A direct proof has been obtained (([M:BP]), for a result of Hall on the bound for the L^1 norm of the derivative of a star-like function of order 1/2 on the radius of the unit circle.

The Bach-Sorenson algorithm - for testing whether a given integer is a perfect power - has been suitably modified to give the same running time of $\emptyset((logn)^2)$ on the average even for small intervals of length $\emptyset((logn)^{30})$([M:BaN]).

Some work was done in the problem on the estimation of partial sums of certain arith-

metical functions. For example, it is well known that $\sum_{n \leq x} c^{\Omega(n)} \ll x(logx)^{c-1}$ holds for $0 < c < 2$; work on the case $c \geq 2$ and related problems are in progress. (Here $\Omega(n)$ denotes the number of prime factors of n.)

Consider the following problem posed by P. Erdös: Let N denote a sufficiently large integer. Let $B(N)$ denote a subset of minimal cardinality of the set of integers $[1, N]$ such that every n in $[1, N]$ can be written as $b + m^2$ for some integer m and some b in $B(N)$. Estimate the cardinality of $B(N)$ in terms of N.

It is known that $B(N) \geq \frac{4}{\pi} \sqrt{N}$; work is in progress towards a possible improvement of this estimate.

Further, some work on problems involving the estimation of certain exponential sums is also in progress.

Subfactors

The subfactors built out of a commuting square corresponding to a 'vertex model' given by a 'biunitary' were studied. The biunitary matrices in $M_2(C) \otimes M_n(C)$ are classified and the conditions for two biunitaries to be equivalent (i.e.giving rise to isomorphic commuting squares) are derived. Also, it is proved that the 'vertical subfactor' associated with the commuting square is always reducible and the conditions for the 'horizontal subfactor' to be irreducible have been obtained. Using this classification of the biunitary matrices, it is shown that the principal graphs of the horzontal(vertical) subfactor is given by the dual group of a subgroup (a subgroup) of $U(2)$. It is shown that in this way the extended Dynkin diagrams $A_n^{(1)}$ and $D_n^{(1)}$ can be obtained as the principal graphs.

There has been some work ([M:SW2]) on fusion algebras and their relationship with Cartan subalgebras; an off-shoot of these considerations has led to a surprisingly elegant and simple algorithm for constructing fusion algebras from certain kinds of real symmetric matrices; this procedure has already led to several new and interesting examples of fusion algebras. Further, non-Hermitian fusion algebras of small orders have been classified.

A question raised by Klaus Thomsen (which he also mentioned at the IMSc Conference on Operator Algebras) has been resolved ([M:KoS]). To be precise, this problem asks whether the isomorphism-type of an inclusion $H \subset G$ of finite groups is determined by the isomorphism-type of the inclusion $R^G \subset R^H$ of II_1 factors, where R^G denotes the fixed-point subalgebra of the hyperfinite II_1 factor under an outer action of the group G (and where R^H is the fixed-point subalgebra with respect to the (restricted) action of H). (To be entirely accurate, a further technical condition - namely, that the subgroup H contains no non-trivial normal subgroup of G - is needed, in order for the problem to be interesting.) The so-called *standard invariant* of the above inclusion of II_1 factors has been determined, and this has been used to settle Thomsen's question in the negative; thus, it was shown that the permutation group S_4 contains subgroups H and K which are isomorphic to $Z/4Z$ and $Z/2Z \oplus Z/2Z$ respectively - both of which satisfy the non-triviality condition stated above - such that the associated subfactors are isomorphic.

2.1.2 Physics

Mathematical Physics

The dually conjugate Hopf algebras $Fun_{p,q}(R)$ and $U_{p,q}(R)$ associated with the two-parametric Alexander-Conway solution of the Yang-Baxter equation have been studied in detail ([P:CJ])

The universal $\mathcal{T}$-matrix approach has been used to construct the comodules of the quantum algebra $U_q(sl(2))$ by exponentiating the modules of the dual quantum group $SL_q(2)$ ([P:VJ])

Certain symmetry transformations of the Yang-Baxter equation have been used to derive the multiparametric and colored extensions of the quantum group $GL_q(N)$ and the Yangian algebra $Y(gl_N)$ ([P:BRJ]).

The study of (p,q)-hypergeometric series by Burban and Klimyk (1994) has been generalized to a more general (P,Q)-hypergeometric series and some related interesting results like the (P,Q)-binomial theorem have been derived ([P:J]).

Results in the Index theory of von Neumann algebras and the connection to braid statistics led to the idea of formalising the concept of fractional statistics in two dimensions. With this in view, studies have been made on algebraic quantum field theory, its application to quantum statistics and its relevance to non-relativistic physics.

Dynamics has been generalized to a noncommutative phase space. The noncommuting phase space is taken to be covariant under the quantum group $GL_{q,p}(2)$. The q-deformed differential calculus on the phase space is formulated and using this, both the Hamiltonian and Lagrangian forms of dynamics have been constructed. In contrast to earlier forms of q-dynamics, our formalism has the advantage of preserving the conventional symmetries such as rotational or Lorentz invariance ([P:MMR1]).

Existing literature on the differential calculus for the Manin space uses a q-deformed Grassmann algebra for the differentials. Construction of a new differential calculus on a multidimensional noncommutative quantum space, with an entirely different algebra for the differentials, has been achieved.([P:MMR2])

A complete Fock space representation of the covariant differential calculus on quantum space is constructed. The consistency criteria for the ensuing algebraic structure, mapping to the canonical fermions and the bosons and the consequences of the new algebra for the statistics of quanta are analysed and discussed. The concept of statistical transmutation between bosons and fermions is introduced. ([P:MR,M3]).

The research work on the extraction of new summation theorems and transformations for generalized hypergeometric series in one and two variables from the study of the five types of doubly stretched 9-j angular momentum recoupling coefficients has been completed ([P:VPR1,VPR2,Sri2])

The concept of restricted compositions has been generalized. Let the number of compositions of n into m parts, in which the i-th part, λ_i (say), satisfies the condition $K_i \leq \lambda_i \leq L_i$, for $1 \leq i \leq m$, be denoted by $c(K_1, K_2, \ldots; L_1, L_2, \ldots; m, n)$. Generating functions for these compositions, algorithms to generate them and their symmetry properties were found. Surprisingly, the algorithm yielded an identity in which a multiple series collapses to just a

single binomial coefficient ([P:RA]). Some particular cases of this function have been found in literature.

Classical Mechanics, Quantum Mechanics and Non-linear Dynamics

Studies have been made on the reduction to one dimension of the two-dimensional anyon model, and its relation to certain one-dimensional models related to the integrable Calogero-Sutherland model ([P:V]).

A many-body Hamiltonian with novel correlations in two-dimensions was introduced earlier by Murthy, Bhaduri and Sen in 1996. A detailed discussion of the exact solutions for arbitrary number of particles has now been completed. In particular it has been shown that the two-body problem is completely solvable and reduces to solving a known differential equation due to Heun. Probably, this is the first time one has encountered Heun's differential equation in many body quantum mechanics. Since the interaction is singular, the "ultraviolet" regularization needed to get finite energy solutions for general inverse-square potentials has been clarified and its implication, specifically to the model studied, has also been discussed ([P:BKLMS]).

The effect of diffractive scattering on the Gutzwiller trace formula (for the oscillating part of the quantum density of states) is being looked at. The classical periodic orbit theory does not account for the diffraction effects which are expected to reproduce the quantum corrections. While a preliminary theory of this exists, scattering effects in the presence of flux lines are non-trivial. Attempts are on the way to develop a systematic method by which one can work out these quantum corrections.

The nonnegativity of the density operator of a state is faithfully coded in its Wigner distribution, and this places constraints on the moments of the Wigner distribution. These constraints are presented in a canonically invariant form which is both concise and explicit. Since the conventional uncertainty principle is such a constraint on the first and second moments, the present result constitutes a generalization of the uncertainty principle to all orders. Possible application to the exciting current activity in quantum state reconstruction using optical homodyne tomography is indicated [P:Sim, SM].

Hilbert space of an oscillator is identified with the Hilbert space of a planar rotor with an additional Z_2 gauge invariance.Well known techniques of gauge theories can be therefore applied. New and inequivalent descriptions of the oscillator states are obtained from different realizations of the Z_2 action. Close relation to a particle in a box and to the cosine and sine states of Susskind and Glogower are pointed out. In each description the phase has the spectral range $[0, \pi)$ and the time evolution has a very simple description.It is argued that a particular gauge fixed version describes the oscillator in the phase basis.This provides the simplest description though there are some new rules to be adopted. Phase operator and the nuber phase uncertainty relations were also explored ([P:Sh1].)

Unique set of coherent states for the anharmonic oscillator was obtained by requiring i. under the quantum mechanical time evolution a coherent state evolves into another, governed by trajectory in the classical phase space (of a related hamiltonian); ii. the resolution of identity involves exactly the classical phase space measure.The rules are invariant under unitary transformations of the quantum theory and canonical transformations of the clas-

sical theory. The states are almost, but not quite, minimal uncertainty wave packets. The construction can be generalized to quantum versions of integrable classical theories ([P:Sh2])

Coherent states were constructed for several systems obeying criteria which required the states to evolve classically and resolve identity using the phase space measure.

Nonlinear dynamics of a classical inhomogeneous ferromagnetic chain has been analysed using a surface geometric formulation, to obtain an interesting class of solutions for the spin configurations ([P:BG]).

A certain transformation has been shown to map general curve evolution equations to solvable forms of the modified Belavin-Polyakov equation ([P:BB])

Diverse physical systems which can be described in terms of surfaces and moving curves have been reviewed highlighting the interesting connections between nonlinearity and geometry ([P:B1,B2]).

Exact nonlinear spin wave solutions have been found in certain classes of classical magnetic chains ([P:BD]).

Curved magnetic films have been shown to have a cusp at a critical, one-soliton point, and its relation to geometric phase has been pointed out ([P:BS]).

The existence of transient (non asymptotic) "$1/f$ noise", occuring over reasonably long time scales, in certain extended nonlinear systems has been reported. These studies contribute towards establishing that transient phenomena, which is often quite relevant in numerical and laboratory experiments, can hold a wealth of interesting dynamical features ([P:Si1])

The novel implications of non-simultaniety and varying rates of information propagation in complex interactive systems have been studied ([P:PSC]).

Prototypical models have been constructed for globally coupled maps on lattices with space-time hierarchy and the rich dynamics arising from the models has been investigated ([P:SPC]).

The roughening of spatial profiles in the presence of parameteric noise in the synchronous phase of the coupled map lattice has been studied, and a host of interesting scaling laws have been found ([P:Si2,Si3,Si4])

Optics

Classical and Quantum Optics

The radiometric brightness theorem for a generalised radiance function is established, and used to study the propagation of the recently discovered twisted Gaussian Schell-model beam in paraxial optical systems. In particular, the phenomenon of focal shift occuring in imaging by wavefields of this kind is examined, and the effects of partial spatial coherence and beam twist are elucidated [P:SFW].

A new operator-based condition for distinguishing classical from nonclassical states of quantised radiation is developed. It exploits the fact that the normal ordering rule of correspondence to go from classical to quantum dynamical variables does not in general maintain positivity. It is shown that this approach naturally leads to distinguishing several layers of increasing nonclassicality, with more layers as the number of modes increases. A nontrivial intrinsically two-mode generalisation of the notion of subpoissonian statistics, which goes beyond all possible single-mode projections, is achieved [P:AMS1].

It is shown that Gaussian states are either classical or strongly nonclassical, but never weakly nonclassical, and that the onset of squeezing signals the transition from the classical to the strongly nonclassical regime. Interesting consequences for the photon number distribution, and explicit representations for them, are derived. The effect of inefficient detectors in measurement of nonclassicality is examined, and the results are compared with recent experiments [P:AMS2].

Results from the classical Stieltjes moment problem are exploited to bring out the totality of all the information regarding phase insensitive nonclassicality of a state as captured by the photon number distribution p_n. Central to this approach is the realization that $n!\,p_n$ constitutes the sequence of moments of a (quasi) probability distribution, notwithstanding the fact that p_n can by itself be regarded as a probability distribution. This leads to classicality restrictions on p_n that are local in n involving p_n's for only a small number of consecutive n's, enabling a critical examination of the conjecture that oscillation in p_n is a signature of nonclassicality [P: SSAM1, SSAM2].

Charged-Particle Optics

Quantum mechanics of the optics of charged particle beams passing through electromagnetic optical systems, like in electron beam devices and accelerators, is being investigated thoroughly, at the Institute, during the past decade using the appropriate basic equations (Schrödinger, Klein-Gordon and Dirac equations). Recently, a systematic procedure to obtain the quantum mechanical corrections to the various classical formulae such as the transfer maps and aberrations coefficients for spin-less and spin-1/2 particles has been developed. This theory is of importance for ion optics and electron optics (or electron microscopy) ([P:JK1]).

In the context of accelerator physics, a new formalism for the beam optics of the Dirac particle has been developed which shows how to obtain directly the quantum-corrected phase-space and spin transfer maps across magnetic quadrupole systems including the Stern-Gerlach kicks and the Thomas-Bargmann-Michel-Telegdi spin evolution ([P:CJKP,K]).

Traditionally, both electron microscopy and accelerator physics depend on classical mechanics and classical electrodynamics for the design of their optics. Possible implications of the quantum corrections to the classical formalism of charged-particle optics is being studied, particularly from the point of view nonlinear phenomena (or aberrations) in electron microscopy and accelerator optics ([P:JK2]).

Condensed Matter Theory and Statistical Physics

The Condensed Matter Group largely works on current problems in strongly correlated fermion systems, low dimensional boson/fermion systems, statistical mechanics, soft condensed matter physics, materials physics, chemical physics and biological physics.

Quantum Hall and Strongly Correlated Fermions

There has been growing experimental evidence that the charged quasiparticle excitations about the $\nu = 1$ quantum Hall state in GaAs heterostructures are extended objects called skyrmions with spin significantly greater than 1/2. Evidence for the skyrmion nature of the

charged excitations was also found in exact diagonalization studies of a few-electron hamiltonian in a periodic rectangular geometry. It was found that though the spin polarization did not fall very much with the removal of a single electron, there was a dramatic fall to zero when two electrons were removed. This is exactly what is expected from the skyrmion model. In addition, the temperature dependence of the polarization at $\nu = 1$ agreed very well with experiment ([P:CPS]).

The low energy excitations about this ferromagnetic $\nu = 1$ ground state can be described by a Non-Linear Sigma Model (NLSM) in terms of the unit local spin polarization. A study of the hamiltonian framework for this model with a Hopf term showed a modification of the spin algebra with new features ([P:CG]). An explicit calculation of the statistics of individual skyrmions using the NLSM provides an explanation for the peculiar behaviour *vis à vis* the spin statistics theorem ([P:DCGS]).

The ground state of a collection of such interacting skyrmions is a *soft* skyrmion crystal. The phase diagram in the $\nu - T - g$ plane (T : temperature, g : Landé factor), computed within the NLSM, reveals a sequence of structural transitions : Ferro-triangle $\rightarrow$ Néel-square $\rightarrow$ Néel-triangle, driven by a change in the shape of the skyrmions. Quantum fluctuations lead to a skyrmion fluid and a novel orientationally disordered crystal at high and low skyrmion densities respectively ([P:RSS1,RSS2]).

The anomalous normal state properties of the cuprate superconductors has lead to the suggestion that Fermi liquid theory fails in 2 dimensions, leading to a novel quantum state called tomographic Luttinger liquid. In spite of several efforts over the years, this proposal has never been proved or disproved. A new calculational method has been invented which verifies the correctness of the above proposal and surprisingly predicts the breakdown of Fermi liquid theory for $d \leq 3$. It is found that zero sound is responsible for a non trivial rearrangement of the Fermi liquid vacuum, leading to spinon and holon excitations with different velocities. Zero sound is shown to be a collection of $1 + 1$-dimensional quantum anomaly. These issues have important consequences for 3-dim metal physics and for liquid He^3.

A sharp criticism from first principles, of a recently proposed $SO(5)$ unifying theory and several quantum critical approaches to the understanding of high-T_c cuprates has been presented.

Physics in Confined Geometries and Low Dimensional Physics

In recent years the study of fermions/bosons in confined geometries and low dimensions ($d \leq 2$), has gained importance due to the impressive growth in nano-device fabrication technologies and the attainment of nano-Kelvin temperatures. Quantum Dots provide a simple experimental arena for the testing of theoretical ideas emerging from studies of confined and interacting electrons in two dimensions. The recently observed shell effects for a dot with a large number of electrons, can be accurately reproduced using an extended Thomas-Fermi approximation.

Low-lying and vortex excitations of the Bose-Einstein condensate of confined alkali atoms with purely repulsive interactions have been studied semiclassically. A study of the asymptotic form of the low energy quasi-particle excitations of the condensate in the presence of a vortex, suggests that apart from a shift in the z-component of angular momentum of the

modes, the quasi-particle dispersion is unchanged by the presence of the vortex. Finite size corrections to the energy eigenvalues have also been calculated.

Materials Physics

The physics of what makes solids hard and the failure of brittle and ductile materials under applied stress, is not very well understood.

A large class of these hard materials are martensites. Martensitic transformations have come to denote any diffusionless, structural transformation following a fast quench and resulting in a long-lived metastable phase with a high degree of short-range order. On the other hand, infinitesimally slow cooling results in the equilibrium phase (*ferrite*). A unified theoretical approach has been worked out addressing both kinetics and morphology of the nucleation of martensites and ferrites. The dynamics of transformation of martensites is traditionally represented by metallurgists by the empirically obtained time-temperature-transformation (TTT) diagram. Such curves have been derived analytically from the above mentioned unified theory. ([P:RS1,RS2]).

The fracture and breakdown processes in disorded systems have been studied using molecular dynamics simulations. The final rupture may be viewed as a first order phase transition. This transition is preceded by avalanches of all sizes characterised by power laws and scaling equations analogous to driven magnetic systems.([P:RD,ZRSV1,ZRSV2]).

Soft Condensed Matter Physics

The effect of size dispersity of particles on the solid-liquid transition in Lenard-Jones system has been studied. It is found that melting can be achieved by introducing more and more dispersity at a fixed temperature. A rich phase diagram is found which has a first order line, hexatic phase and a multicritical point. The implication of this study in connection with colloidal solutions has been presented. This study has been extended to understand the anomalous behaviour of liquid water, a familiar yet unexplained phenomenon ([P:SRHS,SRS]).

The dynamics of a fluid membrane composed of two different lipid species as they phase separate from each other has been investigated. This has been analysed both using a dynamically triangulated monte carlo and a Langevin dynamics. Phase separation induces morphology changes depending on the lateral mobility of the lipids. When the mobility is large, the familiar labyrinthine spinodal pattern is linearly unstable to undulation fluctuations and breaks up into buds, which move towards each other and merge. For low mobilities, the membrane responds elastically at short times, preferring to buckle locally, resulting in a crinkled surface. The dynamical shapes induced by creating a polymerized patch on an artificial fluid membrane by photo-induced cross linking has also been studied ([P:Rao,SR1,SR2,SR3]).

Nonequilibrium Statistical Physics

The dynamics of ordering of a Heisenberg magnet in the presence of a torque has been studied and its irrelevance for nonconserved dynamics has been shown. For conserved dynamics, the torque is shown to be relevant both for zero temperature quenches and quenches to the critical point ([P:DR]).

Quantum Spin Systems

Systems like $LiHo_{0.167}Y_{0.833}F_4$ undergo a spin glass transition at 1.5K, strongly affected by quantum fluctuations. The quantum spin glass transition and the spin glass phase of the disordered transverse field Ising model at zero temperature have been studied using exact diagonalization coupled with finite size scaling and phenomenological renormalization group analysis. Unlike its classical counterpart, the quantum spin glass phase is replica symmetric ([P:SRC]).

Continuing work on the field theory of the frustrated Heisenberg antiferromagnet on a triangular lattice has revealed the existence of a phase with no long range spin order but neverthless having a gapless excitation. Recent experiments on $SrCr_8Ga_{4-x}O_{19}$ and numerical simulations of a Kagome Lattice Antiferromagnet can be understood within the above approach. ([P:SSh])

The interactions of collective excitations with vortices in a superfluid have been investigated using a recently proposed pseudospin model. The scattering cross sections of collective excitations with a vortex have been calculated in the Born approximation. The dynamics of quantum statistical condensate has been studied in the pseudospin model with special reference to small oscillations.

Chemical Physics

Chemisorbed species significantly modify the physiochemical nature of an electrochemical interface. Inspite of their importance in the areas of heterogeneous electron-transfer reactions, catalysis, chemically modified electrodes and double layer studies, an electronic level description of electrosorption phenomena is still elusive. A model Hamiltonian incorporating the electronic structure of the adsorbate layer with arbitrary coverage and random distribution has been proposed, which gives quantitative estimates of adsorbate charge, its density of states and binding energy ([P:GM]). The formalism is applied to the chemisorption of Cu^{++}/Au electrode. Analysis predicts the possibility of a sharp valence transition in the adsorbed copper atom. A comparative study of the chemisorption of Cu/Au, both in the metal-vacuum and in the electrochemical environment is provided ([P:M1,M2]).

A study of interfacial processes in semiconductor/electrolyte interfaces in response to intensity modulations of incident light has been carried out. The output from the interface include in addition to photocurrents, reflected microwave and photo-luminescence signals. This allows dynamic quantities like interfacial charge transfer/trapping rates, to be accurately determined over a wide frequency spectrum.

Biological Physics

The recent elucidation of the complex assembly of molecules in light harvesting systems in photosynthetic bacteria has generated a lot of interest in the mechanism of energy transfer in photosynthesis. Employing a nearest neighbour tight binding hamiltonian to represent the circular array of pigment molecules in the light harvesting unit (LH1), the matrix elements of excitation transfer between the exciton eigenstates of LH1 and the special pair of reaction centres (RC) have been calculated. The results indicate that the non-zero matrix elements are those that pertain to energy transfer from the lowest non-degenerate and degenerate exciton states of the LH1 to the RC — an outcome of circular symmetry. This seems to

be consistent with the fact, that it is precisely these states of LH1 which are also optically active, thus suggesting highly resonant energy transfer between LH1 and RC.

High Energy Physics, Quantum Field Theory, String Theory and Black-hole Physics

Neutrino Physics

The anomaly in the observed ν_μ/ν_e ratio for the atmospheric neutrinos, in the context of three-flavour neutrino oscillations, has been analyzed. With the heirarchy among the neutrino masses $\mu_3^2 >> \mu_2^2 >> \mu_1^2$, the atmospheric neutrino fluxes depend on $\delta_{31} = \mu_3^2 - \mu_1^2$ and the 13 and 23 mixing angles ϕ and ψ. It has been shown that the allowed regions in the space of these three parameters δ_{31}, ϕ and ψ are strongly constrained by the atmorpheric neutrino data. Combining this result with the earlier result on the solar neutrinos that constrained δ_{21}, ω (12 mixing angle) and ϕ, the ranges of values of the five neutrino parameters which solve both the solar and atmospheric neutrino problems simultaneously have been obtained ([P:NRU])

Time-of-night variation of solar neutrino rate has been investigated in the framework of three-flavour oscillations. This will be of relavance to the Super-Kamioka and Sudbury neutrino detectors. An analytical method of computing the regeneration in the earth has been developed. If day-night effect is seen, it has been shown how the study of the time-of-night variation will allow the determination of the neutrino parameters ([P:NRS1]).

The enhancement of the solar neutrino rate in a real-time detector like Super-Kamioka, SNO or Borexino, due to neutrino oscillations in the moon during a partial or total solar eclipse has been calculated, in the three-flavour framework. This enhancement, if seen, can further help to determine the neutrino parameters ([P:NRS2]).

CP- Violation

A new angular asymmetry has been found, which will make it possible to detect CP violation in B decays without the need for flavour or time tagging. This would provide a simple way to use the large number of B's produced in hadron colliders to detect CP violation. So far this has been considered a challenge. The asymmetry is constructed by adding B and $\bar{B}$ partial rates for $B(\bar{B}) \to K^*(\to K\pi)\ell^+\ell^-$. In particular this addition instead of subtraction is achieved by isolating the interference between S-wave/D-wave and P-wave. Such interference terms switch signs between B and $\bar{B}$. The interference term is easily isolated by its characteristic $\sin(\phi)$ dependence where ϕ is the angle between the planes of $\ell^+\ell^-$ and the K^* decay products $K\pi$. Isolation of the $\sin(\phi)$ and $\sin(2\phi)$ terms gives two new asymmetries. This method is also easily applied to $B_S \to \phi\ell^+\ell^-$. Detecting CP violation using traditional asymmetries for B_s is regarded as a very difficult prospect at B factories.([P:Sir])

Work has also been done to test electroweak vector boson self interactions. Of particular significance are anomalous CP violating (CPV) gauge boson self interactions. If CPV is to originate through the symmetry breaking sector, it would give rise to electric dipole/magnetic quadrupole moment of the W boson. Traditionally, each of the two CPV moments have been constrained by the neutron dipole moment. The contributions of the CP violating anomalous $WW\gamma$ interactions to $b \to s\ell^+\ell^-$ have been studied. Cutoff independent results have

been obtained on $\tilde{\kappa}$ and $\tilde{\lambda}$, by constructing an asymmetry of the above type for the process $B \to K^* \ell^+ \ell^-$. It is shown that a sample of 10^4 $B \to K^* e^+ e^-$ events can yield a bound, $|\tilde{\kappa}| < 0.42$ at 90% C.L., which is much tighter than the recent constraint from D0.([P:SSi])

Quantum Chromodynamics

Perturbative QCD has been studied in the region of low Bjorken x; in particular, use of the double asymptotic scaling to calculate the longitudinal structure function of the proton and to J/ψ production at HERA, both in the inelastic as well as elastic/diffractive regions, has been studied ([P:Ba,SB1,SB2]). The polarised structure function in the same regime is also under study.

An extension of QCD that is both chiral symmetric and asymptotically -free was constructed by the addition of a nearly massless chiral multiplet of scalar fields which was shown to be indistinguishable from conventional QCD by most of the standard precision tests of QCD like R-parameter,$g-2$ for muons,deep inelastic scattering etc. It was shown that only an ultrahigh-precision experiment determining the width of Z-bosons distinguished QCD as the better choice.([P:HS1])

Another extension of QCD was proposed with the addition of a massive chiral multiplet of scalars which has all the features of the model above but is not ruled out by Z-width data.This theory naturally predicts an excess of four jet events that have recently been observed at LEP. It has been shown to stand the test of several critical requirements like suppressed flavour changing neutral currents etc.([P:HS2])

It is argued that the chiral perturbation theory has to be substantially modified for the problem of nuclear forces. Loop effects dominate over tree level effects. The dominant behaviours in the scalar isoscalar channel and multi-nucleon forces were obtained in the chiral limit and for a small explicit breaking. The phenomenon of diverging longitudinal susceptibility in goldstone systems is at the heart of this matter.([P:AHS]).

Lattice Gauge Theories

Simulations show that the $SO(3)$ lattice gauge theory on finite size lattices has metastable states with distinct and unrelated values of $\langle L_a \rangle$, the expectation value of the Polyakov line variable in the defining representation. There is evidence to show that one of them corresponds to the high temperature deconfining phase and the other to the confining bulk phase. The implications for the phase diagram at nonzero temperatures and the finite temperature transition in the continuum theory are presented ([P:CS]).

The constraint equations for SU(2) Lattice Gauge Theory were studied and a parametrization of the SU(2) group elements suitable for expansion about the vacuum configuration was found out.

Quantum Field Theory

A general solution to the Non-Abelian Gauss Law was found for SU(2) gauge theory and it's role as an equation of constraint was investigated. The solution required techniques usually used in gravity and thus pointed out the close connection between the constraint equations of non-abelian gauge theories and gravity.

New and efficient techniques were developed for doing duality transformations for non-abelian gauge theories using generating functionals of canonical transformations. Examples were constructed for abelian and non-abelian cases.

The role of vector-potentials in Bohm-Aharonov effect was critically examined and it was shown that the paradoxical aspects had more to do with velocity-dependence of forces than with gauge potentials.A complete reformulation of Quantum Field Theory in the Abelian case without the introduction of vector potentials has been given.

Black-holes, D-branes and String Theory

An attempt was made to explore if a Hawking radiating black hole can be in equilibrium with the cosmic background radiation by looking for a static, spherically symmetric solution of Einstein equation with precisely matched incoming and outgoing massless radiation. A possibility for dark matter in some astrophysical context was identified.

Touching Hall discs are put in Hamiltonian framework and the edge currents are studied. Ensuring gauge invariance and anomaly cancellation leads to interesting physical consequences like oscillation of currents between the discs. Following this, black holes in 2+1 dimensions are studied through Chern Simons theory and edge states. This formalism is used to compute the entropy and it is found to be in proportion to the circumference of the horizon.

Starting with free massless scalar and spinor fields described by a globally $N = 1$ supersymmetric action, infalling on a Schwarzschild black hole, the outgoing Hawking radiation is shown to break supersymmetry spontaneously, exactly as induced by a heat bath in Minkowski space, with no generation of Nambu-Goldstone fermions.([P:Ma])

Various aspects of black hole physics and string theory are being studied. The exploration of issues relating to D-branes (i.e. solitonic backgrounds of certain kinds obtained in string theory) and their effects in string theory are being pursued. A new kind of interaction of matter fields on the inclusion of back reaction effects on a Schwarzschild black hole has been discovered. This interaction is a delta function kind of interaction, called "ultralocal". The surprising aspect of this interaction is that the fermions and bosons exhibit asymmetry. This interaction is absent in the simplest fermion bilinears, but the scalars do not have this property. This might lead to non-trivial effects on Hawking radiation and give a clue to the information loss problem associated with it ([P:DaM]).

The recent discovery of a microstate counting of black hole entropy from string theory has been investigated. The classical extremal black hole was modelled by microscopic BPS states of D-branes, and their degeneracy was shown to be equal to the area of the black hole in a paper by Vafa and Strominger. However semiclassical arguements show that the entropy of extremal black hole is zero. A resolution of this apparent contradiction has been found by proposing that the string theory black hole actually corresponds to a classical "near extremal black hole", whose entropy is area as determined by semiclassical methods ([P:DDR]).

Recently, it was shown that the emission rates of low energy scalar particles from certain D-Brane configurations exactly match with the Hawking spectrum from the corresponding black holes. It has been shown that the matching persists even in the extreme high energy tail of the spectrum, by including suitable back reaction effects which become important in this regime ([P:DDS,DDMS]).

The role of D-branes and the conifold singularity in Calabi-Yau compactifications in Type IIB string theory has been studied. Using a description of the conifold singularity in terms of intersecting D-branes the singularity structure of higher derivative F-terms (in the target space effective theory) was studied. This description enabled to reproduce the expected structure of the singularity (anticipated from considerations of field theory and duality) directly in the string theory. The calculation is of particular interest because using duality techniques it was in fact possible to do a one-loop calculation that involved a solitonic state going around in the loop. ([P:GJNS])

The problem of descriptions of D-branes wrapped on nontrivial cycles in Calabi-Yau n-folds can be solved easily in the case where the CY n-fold is simply tori. The other cases are more complicated. The simple case of T^2 has been reproduced using the Gepner description of strings moving on CY n-folds. This can now be generalized to the case of K3 and CY 3-folds. The boundary states for D-branes wrapping around cycles on Calabi-Yau or $K3$ manifolds have also been constructed using the minimal superconformal models. The N=2 Landau-Ginzburg description of these D-branes is also currently under investigation.

An attempt has been made to construct a method for obtaining equations of motion in string theory, that is manifestly gauge invariant and also computationally tractable. Some progress has been made in using loop variables to describe string interactions. Earlier the free gauge invariant equations had been obtained using this approach and subsequently some results had been obtained for the interacting case. But only the leading terms hads been obtained so far. Now, in principle, the full gauge invariant interacting equations can be written down. The main idea is to broaden the loop to a band of finite width. The band can be thought of as many interacting strings. Using this technique the equations of the interacting and free theories look the same (except for the broadening). Work is in progress in trying to make precise the proofs of gauge invariance to all orders and also in doing explicit calculations ([P:S2])

Intrinsic and extrinsic geometric properties of string world sheets in a curved space-time background have been explored; in this formulation the only dynamical degrees of freedom of the string are its immersion coordinates. A classical equation of motion and the space-time energy-momentum tensor of the string are obtained. One loop divergent terms have been calculated using the background field method. A divergent Euler characteristic term appears in this order. The condition for one-loop finiteness has been derived. The results thus obtained differ from those in the standard procedure. The one-loop finiteness condition is different from the Ricci flatness condition met in the σ models. It involves the Ricci tensor of the space-time restricted to the world sheet and the scalar curvature of the world sheet. It is interpreted as Einstein equation with a cosmological term proportional to the scalar curvature of the world sheet ([P:VP]).

A generalized action for strings which is a sum of the Nambu-Goto and extrinsic curvature (the energy integral of the surface) terms, has been used to couple strings to gravity. It has been shown that the conical singularity has a deficit angle that has contributions from both the above terms. It is found that the effect of the extrinsic curvature is to oppose that of the NG action for the temperature of the black-hole. It thus favours stability against evaporation. The entropy-area relation is modified indicating a stretched horizon for the black-hole ([P:PV]).

M- theory

Recently there has been a lot of interest in matrix models following a proposal that large N supersymmetric Yang Mills theory is a possible non perturbative description of string theory. There are many outstanding questions that arise immediately. One is the nature of the double scaling limit. Another is the connection with standard perturbative string theory. There is also the hope of understanding duality symmetries better. Some of these issues have been looked at. the nature of the double scaling limit has been clarified by looking at the non-planar Feynman diagrams of these matrix models. One finds that the size of the matrix has to scale as some power of the volume of space time. The precise power seems to depend on the choice of vacuum. Thus tuning this power may be a way to probe different vacua. It has been shown how one can reproduce some simple vertex operators in the matrix model description. A proposal has also been made that the duality symmetry may be related to a symmetry between different choices of matrices as backgrounds about which perturbation is to be done. If this proposal is right then symmetries such as the SL(2,Z) of Type IIB strings can be made much more manifest. Work is under way in clarifying these and other issues ([P:S1])

The conjectured non-perturbative S-duality symmetry of Superstring Theories were applied as a solution generating technique to obtain full type IIB plane wave string backgrounds in ten dimensions. It was shown that these backgrounds were exact to all orders in α' through a completely geometrical analysis based on a covariantly constant null Killing isometry. Subsequently this was generalised to obtain IIB analogs of K-model string backgrounds and these were also shown to be exact provided the vector like couplings in the Brinkmann metric were linear in the transverse coordinates. The issue of arbitrary couplings were also investigated. In this case it was necessary to employ the generalized curvature approach with suitable modifications to include the Ramond-Ramond antisymmteirc tensor field. Assuming the existence of certain field redefinitions it could be shown that the corresponding type IIB backgrounds were exact if the couplings were chiral. A complete study was made of the recent discovery of topological defects in String Theory called Dirichlet branes. Various connections of the type IIB backgrounds alluded to in the previous section with D-branes and the D=11 M-theory are being currently pursued. In this connection extensive studies are also being made on the conjectured Yang-Mills Matrix Quantum Mechanics description of D=11 M-Theories on the D-zero brane world volume in the corresponding strongly coupled IIA string theory. The role of oscillating string backgrounds in the context of these Matrix Models are being currently investigated ([P:Se,KKS,KS]).

2.1.3 Theoretical Computer Science

Algorithms & Complexity

Complexity Theory

A key result concerning the Nisan-Wigderson pseudorandom generator has been extended to an appropriate nondeterministic setting. This enables one to derandomize some randomized complexity classes, notably BP.Σ_k^p and BP.Θ_k^p, under plausible assumptions on the resource-bounded measure of certain complexity classes([T:AK]).

An enhancement of Angluin's model for exact learning has been defined and studied. It has been shown that the enhanced model allows a sharper classification of certain concept classes with respect to exact learnability([T:AV2]).

Algorithms

The special position occupied by the problem of computing the determinant of a matrix with integer entries, as the representative problem for GapL, was explored. This study led to the discovery of a combinatorial approach to computing the determinant([T:MV]). The new algorithm is division-free and works in any commutative ring, lends itself to reasonably efficient sequential, parallel and circuit implementations, and its proof of correctness is entirely combinatorial (all earlier algorithms relied on linear algebra methods).

An improved upper bound on the number of Carmichael numbers $\leq x$, with three prime factors has been obtained ([T:BN]). Some new results on the problem of finding the least witness of a composite number have also been obtained. Progress has been made towards a conjecture of S.W. Graham on Carmichael numbers with three prime factors.

It has been shown that the Max2Sat problem remains NP-complete even if every variable appears in at most three clauses. When every variable appears at most twice, it has been shown that the problem can be solved in linear time. An efficient exact algorithm has also been obtained for MaxSat when every variable appears at most three times([T:RRS]).

Approximate algorithms for the MaxSat problem, including some classical algorithms and the recent semi definite programming based ones, have been surveyed in a Master's thesis submitted to Anna University.

Data Structures

The problem of efficient representation of static binary trees has been studied. Earlier information-theoretically optimal representations allow only some of the following operations at a node in a static tree to be performed in constant time: *left child, right child, parent, the number of children rooted at the node.* A new information-theoretically optimal representation for static binary trees has been obtained through a representation of balanced parantheses sequence([T:MuR]). In this representation all the above operations are performed in constant time. This representation has been extended to an efficient representation for planar graphs where adjacency can be checked in constant time.

Parameterized Complexity

The parametrized complexity of the two important problems, MaxSat and MaxCut has

been explored. It has been argued that the standard way of parametrization for these problems is unsuitable, because under the standard parameterization non-trivial situations arise only for large parameter values, when fixed-parameter tractable algorithms are infeasible. It is well known that any graph with m edges has a cut of size at least $m/2$ and any boolean CNF formula with m clauses has an assignment that satisfies at least $m/2$ clauses. It has been shown that these problems remain fixed-parameter tractable even if we parameterize beyond the guarantee values (i.e if we ask whether there is a cut of size $m/2+k$ in the graph or an assignment satisfying at least $m/2+k$ clauses in a formula)([T:MR]).

A fixed-parameter algorithm for vertex cover to decide whether there is a vertex cover of size k in a graph on n vertices has been obtained ([T:BFR]). The time taken by this algorithm is $O((1.324718)^k k^2 + nk)$. This improves the earlier best algorithm for the problem that takes $O(2^k n)$ time.

An irredundant set in a graph is a subset of vertices V' such that for every vertex in V', there is a neighbour (which could be itself) that is not adjacent to any other vertex of V'. The parameterized complexity of irredundant set was open for quite some time. It has been shown that the problem is hard for the complexity class $W[1]$([T:DFR]). This essentially means that it is unlikely that in $O(f(k)m^{O(1)})$ time we can find out whether the given graph has an irredundant set of size k. On the other hand it has also been shown that the co-irredundant set problem, which asks whether the graph has an irredundant set of size $n-k$, is fixed-parameter tractable meaning that such an algorithm is possible.

A detailed survey was prepared on various techniques to prove a parameterized problem fixed-parameter tractable. The survey also contains a brief introduction to the theory of parameterized intractability ([T:R]).

Theory of Distributed Systems

Automata

Regular languages over strings, defined by regular expressions, have a characterization in terms of finite-state automata using Kleene's theorem. Here, regular languages over series-parallel posets, defined by extending regular expressions with a parallel operator, have been studied. These have been characterized using finite-state automata which allow fork and join transitions.

Work on decomposition of finite state systems to get suitable models for easy verification of distributed systems is being continued. The class of regular trace languages was characterized using an assumption-commitment framework ([T:MoR]).

Some results were obtained on compositional verification of Hybrid systems in Duration Calculus.

Temporal Logic

The on-the-fly algorithm for linear time temporal logic with actions was extended to product-linear temporal logic ([T:DM]).

The satisfiability problem for linear time temporal logic asks whether a given formula has an infinite run of some system as its model. When runs of systems are equated by identifying interleavings, the strong satisfiability problem asks for an equivalence class of runs satisfying a given formula. This problem was shown to be undecidable, and a subclass of formulas was

identified, on which the problem is elementarily decidable ([T:R1]).

Logics of Knowledge

A logic of knowledge was studied where a reasoner has explicit knowledge of only those facts that hold in states of the system which are visible to the reasoner. This lends a finer distinction between notions of implicit and explicit knowledge than studied so far, and offers another solution to the logical omniscience problem ([T:R2]).

Detailed lecture notes were prepared on two themes: one set up basic background in modal logic, leading to dynamic logic and logics of knowledge, with an emphasis on completeness and decidability theorems ([T:R3]); the other surveyed recent literature where similar techniques are being used in agreement problems in distributed computing and consensus problems in game theory. These notes formed a basis for tutorial presentations on these subjects([T:R4]).

Finite Model Theory

The (limitations of) expressive power of generalized quantifiers on finite models have been studied in the last few years. For instance, it has been shown that no finite set of such quantifiers can be added to fixed point logics to capture exactly the corresponding complexity classes. These results have been strengthened and also extended to implicit definability([T:S]).

A strong necessary condition on classes of structures on which PFP can capture $PSPACE$ in the presence of finitely many generalized quantifiers has been shown. For IFP and $PTIME$ the limitation of expressive power of generalized quantifiers are shown only on some specific nontrivial classes. A nearly complete characterization, of classes of structures on which $IMP(PFP)$ can capture $PSPACE$ in the presence of finitely many generalized quantifiers, has been obtained.

A new proof of one of the known results, characterizing the classes of structures on which $L^{\omega}_{\infty,\omega}(\mathbf{Q})$ collapses to $FO(\mathbf{Q})$, where $\mathbf{Q}$ is a set of finitely many generalized quantifiers, has been given. This proof easily generalizes to the case of implicit definability, unlike the quantifier elimination argument used in the known proof which does not easily get adapted to the implicit definability setting. This result shows the limitation of expressive power of implicit closure of $L^{\omega}_{\infty,\omega}(\mathbf{Q})$.

The technique of quantifier elimination has been adapted to show that $IMP(L^k(\mathbf{Q}))$ types can be isolated in the same logic. In addition, type equivalence questions for some other variants of implicit definability were also examined.

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2.3 Conferences/Workshops held at IMSc

2.3.1 International Conference on Operator Algebras

This conference, held during the period January 6th to 11th, 1997, is the first major international conference on operator algebras to be held in India. It was made possible by funding from the Department of Science and Technology, the National Board for Higher Mathematics, as well as from the Institute of Mathematical Sciences. In addition, a generous funding from the International Mathematical Union made it possible to provide partial travel support for quite a few of the foreign delegates. This conference was convened by V.S. Sunder of this institute.

The conference was attended by about 20 Indian and an equal number of foreign mathematicians, and the general verdict was that it was a very good conference.

The Principal Speakers:

The forenoon sessions (on the 6 days of the conference) were devoted to courses, of three 90-minute lectures each, by four 'principal speakers'; these courses were as follows:

Voiculescu UC, Berkeley	:	Topics in Free Entropy
Ocneanu Penn St. Univ.	:	The classification of connections and intermediate subfactors
Haagerup	:	(1) Subfactors and their principal graphs - a survey based on examples
Odense Univ.	:	(2) Spectral analysis of certain non-normal elements in free group factors
Skandalis Univ. of Paris	:	Kasparov's K-theory, Conjectures of Novikov and Baum-Connes

Afternoon lectures

The afternoon sessions were devoted to 30 minute lectures by several of the remaining participants. The speakers and titles of their talks are given below.

Huzihiro Araki	:	Application of operator algebra methods to physical models
Ola Bratteli	:	Multiresolution wavelet theory of scale N and representations of the Cuntz algebra O_N
Erling Stormer	:	Entropy in operator algebras
Nobuya Sato	:	Two subfactors arising from a non-degenerate commuting square
Klaus Thomsen	:	Factors and subfactors from Ergodic theory
Judith Packer (Jesudasan)	:	The Equivariant Brauer Group and Crossed Product C^*-Algebras
Ajay Kumar	:	Equivalence of norms on operator space tensor products of C^*-algebras
Arup Pal	:	Contraction technique and Haar measure for the $E(2)$ group
Hans Wenzl	:	Subfactors from quantum groups - a general construction
David Evans	:	Automorphisms of amenable C*-algebras and the Rohlin property
Fred Goodman	:	Path idempotents
Florin Radulescu	:	Some aspects of quantum dynamics and quantization in type II_1 factors
Robin Hudson	:	Generalised Boson-Fermion correspondence via quantum stochastic calculus
Rajarama Bhat	:	A generalised intertwining lifting theorem
K.R. Parthasarathy	:	A class of Lie super-algebra representations arising from quantum stochastic calculus
Masaharu Kusuda	:	C^*-crossed products of C^*-algebras with the weak Banach-Saks property
Yasu Kawahigashi	:	Quantum doubles and Orbifold subfactors
Carl Winslow	:	Endomorphisms, automorphisms and subfactors of von Neumann algebras
Yasuo Watatani	:	Jones index theory for simple C^*-algebras
Subhash Bhatt	:	Quasi-weights and unbounded operator algebras

2.3.2 Workshop on Special Functions & Differential Equations

This workshop was held from January 13 to January 24, 1997. It was cosponsored by the the Council of Scientific and Industrial Research and the Department of Science and Technology of the Government of India, the Indian National Science Academy, the National Board for Higher Mathematics of India, the International Center for Theoretical Physics (Trieste, Italy) and the European Commission (Brussels, Belgium). The conference was convened by K. Srinivasa Rao of this institute.

There were about 75 participants in this workshop, with approximately two thirds from India. The other participants were from Belgium (7), The Netherlands (3), Australia (2), New Zealand, Finland, Canada, Poland, Germany, Austria, France, Italy and the United States of America (each 1), and some non resident Indians.

During the workshop there was also an informal meeting for founding a Society for Special Functions & Applications in India. Its aim is to promote research in this area, disseminate information as to what is going on, and possibly to create a new India-based forum for bringing out research publications of international standard on special functions. Application forms for life-long membership were made available. Interaction with the SIAM activity [3] group was considered as highly desirable by all present at the discussions, especially concerning the possibility of circulating the Newsletter with additions from the Indian side.

The proceedings of the workshop are being edited by K. Srinivasa Rao, R. Jagannathan, G. Vanden Berghe and J. Van der Jeugt, and will be published by the Allied Publishers Ltd. The publication is expected to be released before the end of this year.

The academic programme was as follows:

[3] also see the Report by Tom H. Koornwinder and Walter Van Assche, in the Newsletter, SIAM Activity Group on Orthogonal Polynomials and Special Functions, Volume **7**, Number 2, February 1997.

A.K. Agarwal	:	q-Special Functions and Combinatorics
R.P. Agarwal	:	Ramanujan's Mock theta functions : Problems and Prospects
R. Balakrishnan	:	General structure of certain ubiquitous non-linear Partial Differential Equations in Physics
H. Bavinck	:	Differential operators having Laguerre type and Sobolev type Laguerre orthogonal polynomials as eigen functions : a survey
J. Beckers	:	On non-linear sl(2) algebras and the angular momentum theory
S. Bhargava	:	Unification of cubic analogues of Jacobi's theta function
G. Bhatnagar	:	A multivariable view of one-variable q-series
F. Calogero	:	Generalized Lagrangian interpolation, finite-dimensional representations of shift operators, remarkable matrices, trigonometric and elliptic identities Special lecture : "A Nuclear-Weapon-Free World : Desirable? Possible? Probable?"
A. Chakrabarti	:	Role of special functions in problems of fluid mechanics
S. Chaturvedi	:	Jack polynomials and their applications to Physics
S. Cooper	:	New Proofs of the Macdonald Identities
R.Y. Denis	:	On certain q-series and continued fractions of Ramanujan
V. Fack	:	Racah coefficients, general recoupling coefficients and graph theoretical methods
R. Jagannathan	:	(p, q) - Special functions
T.H. Koornwinder	:	Special functions associated with root systems
V. K. B. Kota	:	Group theoretical aspects of $U(18)$ and $U(6) \times U(20)$ Bose-Fermi and other related symmetry schemes
M. Lakshmanan	:	Localized structures in (2+1) dimensional non-linear evolution equations
L. Lapointe	:	Creation Operators for Jack and Macdonald Polynomials and Integrable Systems
R.P. Malik	:	KdV-type equations from non-linear realization method
M. Lohe	:	Quantum group derivation of some special function identities
H. L. Manocha	:	Hypergeometric Functions and Lie Theory
N. Mohan Kumar	:	Some results in IMT and tanh quadratures
P. Nattermann	:	Quantization, non-linear Quantum Mechanics and Doebner - Goldin equations
M.A. Pathan	:	Lie theoretic approach to generalized Bessel functions

P.R. Parthasarathy	:	Orthogonal polynomials, birth and death process and continued fractions
R. Parthasarathy	:	$SU_q(2)$ and q-Wigner functions
S. Ponnuswami	:	On Ramnujan's Asymptotic Expansions and inequalities for hypergeometric functions
J.S. Prakash	:	Special functions for SU(3)
C. Quesne	:	Coloured Hopf Algebras
G. Rajasekaran	:	Fock space and non-commutative calculus
S.K. Rangarajan	:	Appell Polynomials, asymptotics and continued fractions - a miscellany
A. Ronveaux	:	Connection Coefficients between two families of Orthogonal Polynomials; Generalized linearization problems; Fourth order Differential or Difference Equations for Orthogonal Polynomials and Connection Problems
R. Sahadevan	:	Lie symmetries and linearization of difference equations
T. Sahoo	:	On three unifired approaches in problems of scattering of water waves by vertical barriers
T.S. Santhanam	:	Finite quantum systems and Kravtchuk polynomials
M. Schlosser	:	Multidimensional matrix inversions and multiple basic hypergeometric series associated to root systems
H.S. Sharatchandra	:	Polynmial representation of model space of $SU(3)$
R. Simon	:	From polynomials to generalized quantum mechanical uncertainty principles
K. Srinivasa Rao	:	Angular momentum coupling and recoupling coefficients and generalized (ordinary and basic) hypergeometric functions
V. Srinivasan	:	Operator methods and special functions
P.R. Subramanian	:	Zeros and starting points of the Hermite polynomials
F.H. Szafraniec	:	How some operational formulae revive in the Hilbert space environment
W. Van Assche	:	Approximation Theory and Analytic Number Theory
G. Vanden Berghe	:	Mono-implicit Runge-Kutta Nyström methods for first- and second-order ODEs
P.J. Van der Houwen	:	Parallel Algorithms for solving stiff and nonstiff initial value problems; Parallel linear system solvers and parallelism across time
J. Van der Jeugt	:	New addition formulas for special functions and their q-analogues from tensor product decompositions; Transformation and summation formulas for multiple hypergeometric series
A. Verma	:	Transformations of basic hypergeometric series and their applications
D.N. Verma	:	A canonical q-interpolation between Clifford and the Universal Heisenberg algebras
M. Vourinen	:	Hypergeometric functions in geometric function theory
M. Waldschmidt	:	Extrapolation with interpolation determinants
N. Witte	:	Many-body orthogonal polynomial systems

2.3.3 Instructional Conference On Nonlinear Functional Analysis

Nonlinear Functional Analysis is an area of active research in mathematics with applications to several disciplines like geometry, mathematical physics, partial differential equations etc.. The curricula in most Indian universities do not include this subject. Therefore an instructional conference was proposed to be conducted in order to introduce the subject to young research scholars.

This Conference was held from February 3 to February 21, 1997; it was financially supported by the National Board for Higher Mathematics; and it was organised by S. Kesavan of this institute, with the assistance of Professors Adimurthi and P.N. Srikanth of the TIFR Centre, Bangalore.

The Conference consisted of lecture courses given by experts in various topics of current research interest in nonlinear functional analysis. The participants were mainly research scholars, post-doctoral fellows and lecturers from various Indian Universities and Institutes of higher learning. In addition there were several local participants from Madras.

The academic programme consisted of three 90- minute lectures per day for five days a week. There were three lecture courses per week. The first week was devoted to basic topics in functional analysis and linear partial differential equations and was meant to bring to the same level all the participants who have had diverse kinds of training.The courses were on Distributions and Sobolev Spaces, Linear Partial Differential Equations and the theory of the Topological Degree.

The second week went on to cover classical but more advanced topics like Variational Methods for Solving Nonlinear Equations, Schwartz Symmetrization and Isoperimetric Inequalities and Bifurcation Theory.

The final week was devoted to courses dealing with topics of current interest such as the Method of Compensated Compactness, the Method of Compactness by Concentration (covering the work of Fields Medallist P. L. Lions) and Morse Theory (including a discussion of E. Witten's proof of the Morse Inequalities).

The lecture courses were so designed that later courses drew heavily on the topics covered by the earlier ones and thus the entire school had a coherent theme, viz. methods for solving nonlinear partial differential equations.

The following is the list of lecturers and the topics of their lectures.

A. K. Nandakumaran	TIFR, Bangalore	Distributions and Sobolev Spaces.
S. Kesavan	IMSc, Chennai	Theory of the Topological Degree.
G. D. Veerappa Gowda	TIFR, Bangalore	Linear PDE.
Mythily Ramaswamy	TIFR, Bangalore	Bifurcation Theory.
S. L. Yadava	TIFR, Bangalore	Calculus of Variations.
S. Kesavan	IMSc, Chennai	Symmetrization and Isoperimetric Inequalities.
K. H. Paranjape	IMSc, Chennai	Morse Theory.
Adimurthi	TIFR, Bangalore	Method of Compactness by Concentration.
M. Vanninathan	TIFR, Bangalore	Compensated Compactness.

The lecturers prepared hand-written notes which were photocopied and distributed to the participants. Several people have evinced a keen interest in the lectures and have requested the Organizers to publish the lecture notes. The Organizers have accordingly requested the speakers to prepare the notes in publishable form and hope to bring out the proceedings with as little delay as possible.It is hoped that the NBHM will support this venture as well.

2.3.4 Symposium on Neurosciences

This symposium was held in the institute (on 26/4/97) to honour Brigadier Dr. B. Ramamurthy, on the occasion of his 75th Birth Anniversary. This meeting was sponsored by the Indian National Science Academy (Madras Chapter) and the Institute of Mathematical Sciences.

The speakers were :

Dr. G. Rajasekaran who welcomed and felicitated Dr. B. Ramamurthy;

Dr. K. Srinivasa Rao on *Dr. B. Ramaurthy the Neuro-surgeon*;

Dr. S. Kalyanaraman (Neurosurgeon) on *MRI : solved and unsolved problems*;

Dr. Ramesh Anishetty on *Neural networks*;

Dr. T. S. Radhakrishnan on *SQUID: Application to Neurosciences*;

Dr. A.V. Lakshmanan on *Positronium Emission Tomography (PET)*;

Dr. B. Ramaurthy on *Excitement in Neurosciences*;

Dr. V. Ramamurti (President, INSA Madras Chapter) proposed a Vote of Thanks on the occasion.

2.3.5 Update Meeting on Timed Systems

Temporal logics and automata on infinite sequences have been extensively studied in the context of reasoning about distributed systems. While these logics abstract away from explicit reference to time, it does seem necessary to reason quantitatively about time in the context of systems which interact with physical processes. In the last ten years, there have been many research proposals for studying **timed systems**, in many a setting: automata, temporal logics, process algebras, and so on. Particularly interesting are studies of *hybrid systems*, which consist of discrete as well as continuous variables.

This meeting, held during the period June 16th to 20th, 1997, was an attempt to bring together researchers in the theory of distributed systems in India and update ourselves on

progress in this area. The format was of tutorial presentations which surveyed specific approaches (from a critical perspective). This meeting was convened by R. Ramanujam of this institute, together with Paritosh K. Pandya (TIFR, Mumbai).

It was a small topical meeting, with about twenty active researchers from IMSc, SMI, TIFR, IISc, ISI (Calcutta), IIT (Mumbai) and IIT (Kharagpur). There was only one participant from outside India, from UNU(Macau).

The following speakers lectured on the following topics:

Speaker	**Institute**	**Title**
Deepak D'Souza	SMI, Chennai	Timed regular expressions
K. Narayan Kumar	SMI, Chennai	Timed automata
Kamal Lodaya	IMSc, Chennai	Monadic second order logics and timed sequences
Swarup Mohalik	IMSc, Chennai	Models of reactivity
Madhavan Mukund	SMI, Chennai	Hybrid automata
Paritosh Pandya	TIFR, Mumbai	Interval logics and Duration Calculus
Xu Qiwen	UNU, Macau	Proof theory for Duration Calculus
R. Ramanujam	IMSc, Chennai	Timed temporal logics
S. Ramesh	IIT, Mumbai	Synchronous languages
Suman Roy	IISc, Bangalore	Neighbourhood logic
R.K.Shyamasundar	TIFR, Mumbai	Synchronous languages
P. S. Subramanian	TIFR, Mumbai	Combining temporal logic systems

2.4 Seminars

Date	Speaker Affiliation	Title
10-5-1996	Vijay Kodiyalam IMSc	Nori's proof of the Riemann-Roch theorem I
14-5-1996	Rama Mishra MRI, Allahabad	Polynomial representation of torus knots
17-5-1996	Vijay Kodiyalam IMSc	Nori's proof of the Riemann-Roch theorem II
5-6-1996 12-6-1996 19-6-1996	R. Ramanujam IMSc	Three lectures on Kamp's theorem
26-6-1996	Ravi Kannan Carnegie Mellon Univ. USA	Regularity Lemma and its applications
27-6-1996	Ambar Sengupta Louisiana State Univ. USA	Chern-Simons functional integral: a rigorous approach
1-7-1996	R. Balasubramanian IMSc	Ramanujan (NBHM NURTURE)
3-7-1996	P.A.Viswanath SPIC Math. Inst.	Algebraic curves (NBHM NURTURE)
3-7-1996	R. Ramaswamy JNU	Lattice gases in 1&2 dimensions: traffic models, coarsening and pairwise balance
3-7-1996	Subashis Nag IMSc	Riemann surfaces (NBHM NURTURE)

8-7-1996	Shubha Tewari UCLA, USA	Fermi liquids and high T_c superconductors
9-7-1996	Subhashis Nag IMSc	The Jacobi Variety and Theta
11-7-1996	A.K. Agarwal Inst. for Adv. Study in Sci. and Tech., Guwahati	New Classes of Partition Identities
12-7-1996	M Muthukumar Univ. of Mass., Amherst, USA	Pattern recognition and topological dereliction in polymers
15-7-1996	M Muthukumar Univ. of Mass. Amherst, USA	Electrophoresis of polyelectrolytes
16-7-1996	J Pasupathy CTS, IISc	On the measurement problem in quantum mechanics
16-7-1996	Subhashis Nag IMSc	The Jacobi Variety and Theta
17-7-1996	Sumathi Surya Syracuse Univ. USA	An analysis of the θ sectors in quantum gravity
23-7-1996	J K Sarma Gauhati University	Q^2-evolutions of structure functions at high-x and low-x
23-7-1996	Subhashis Nag IMSc	The Jacobi Variety and Theta
24-7-1996	Sachin Vaidya Syracuse University USA	Parity doubles in Particle Physics
24-7-1996	Shreedhar Inamdar TIFR, Mumbai	A geometric approach to syzygy questions

25-7-1996	Shreedhar Inamdar TIFR, Mumbai	Frobenius splittings of varieties and appllications
30-7-1996	P.A. Viswanath SPIC Math. Inst.	Geometry Seminar on Theta
30-7-1996	J Anandan University of South Carolina, USA	Gravitational collapse of the wavefunction
31-7-1996	A. P. Balachandran Syracuse University USA	Anamalous defects and their quantised conductivities
2-8-1996	K. Srinivas TIFR, Mumbai	Abelian Group Problem
14-8-1996	Rahul Basu IMSc	Report on Int. Conference on High Energy Physics '96
20-8-1996	Pramathanath Sastry MRI, Allahabad	Torelli theorems
22-8-1996	K. B. Sinha ISI, New Delhi	Mathematical models of damped quantum systems
23-8-1996	P Ramadevi IMSc	Bekenstein - Hawking entropy of extremal stringy blackholes
26-8-1996	James Annett Bristol Univ., UK	Evidence for d-wave pairing in high temperature superconductors
28-8-1996	Balachandran Sathiapalan IMSc	Loop variables in string theory
29-8-1996	Reuben Rabi Kings College London, UK	Hodge theory on π_1.

11-9-1996	Kavita Ramanan Brown Univ., USA	Convex Duality and the Skorokhod Problem
12-9-1996	Kalyan Chakraborty MRI, Allahabad	Serre's conjectures on 2-dimensional Galois representations
12-9-1996	Indranil Biswas TIFR, Bombay.	Projective structures on Riemann surfaces
13-9-1996	Kalyan Chakraborty MRI, Allahabad	On the generalized Fermat problem
13-9-1996	D. Shubashree IMSc	Quantum Antiferromagnets: from Triangular to Kagome Lattice
19-9-1996	B. I. Halperin Harvard Univ., USA	The Quantum Hall Effects: quantized and unquantized
25-9-1996	Amol Dighe Univ. of Chicago USA	CP violation in B mesons
26-9-1996	Kapil Paranjape IMSc	Resolution of singularities
3-10-1996	D. N. Verma TIFR, Mumbai	Inexpensive recipes for representations of symmetric and general linear groups
4-10-1996	Padmanabhan Krishnan Univ. of Canterbury New Zealand	Hybrid Structures
9-10-1996	G.H. Gadiyar IIT, Madras	Unique Deformation of Quantum Field Theory Resulting in Divergence Free Amplitudes
10-10-1996	R. Balasubramanian IMSc	Combinatorial Number Theory a la Erdös

11-10-1996	R. Ramanujam IMSc	Equivalence on runs and PTL
17-10-1996	Srikanth Raghavan Univ. of New Mexico, USA	Memory function approach and related issues in strongly interacting quasi particle boson systems
17-10-1996	D. Indumathi Univ. of Dortmund and IISc	Infrared behaviour of finite temperature QED
18-10-1996	K. R. Parthasarathy ISI, Delhi	The Eyre-Hudson representation of the Lie superalgebra gl(n,k) in terms of quantum stochastic integrals
18-10-1996	Venkatesh Raman IMSc	The Probabilistic Method of Erdös and its Applications
23-10-1996	Meena Mahajan IMSc	A Combinatorial Algorithm for the Determinant
24-10-1996	B.V. Rajarama Bhat ISI, Bangalore	Minimal Dilations of Quantum Dynamical Semigroups
1-11-1996	V. Arvind IMSc	Efficient Checkers for Group-theoretic Computation
8-11-1996	R.P Malik JNR Moscow	Integrablity in Non-linear Realization Scheme
20-11-1996	C. S. Rajan TIFR, Mumbai	Strong multiplicity one for l-adic representations
25-11-1996	N. Mukunda IISc	Coset space topology and the spin of the photon
26-11-1996	Rohini Godbole C.T.S., IISc	Light Stop

28-11-1996	T. Senthil Yale Univ., USA	Quantum Transitions in Random Spin Systems
3-12-1996	Robert V. Moody University of Alberta, Canada	Voronoi and Delaunay cells in the generalized kaleidoscope
3-12-1996	G. Manoj IMSc	Periodic Superstructures in two-component fluid membranes
4-12-1996	Anirvan Sengupta RRI	Who is Afraid of Boundary Conformal Field Theories?
9-12-1996	T. Chakraborty IMSc	Theory of incompressible states in a narrow channel.
10-12-1996	J. Ambjørn Niels Bohr Institute Denmark	Quantum Geometry
10-12-1996	J. I. Munro Univ. of Waterloo, Canada	Finding the Loneliest Point
12-12-1996	C. S. Aravinda ISI, Bangalore	Geometry of knot complements and surgery applications
13-12-1996	K.T. Mahanthappa Univ. of Colorado USA	Inflation below Planck mass and pseudo Nambu-Goldstone boson as inflaton
16-12-1996	Gilbert Ndjatou City University of New York, USA	Discussion on Knowledge Theory
16-12-1996	Ron van der Meyden Univ. of Technology, Sydney, Australia	Discussion on Knowledge Theory (contd.)
17-12-1996	Sanjay Puri JNU	Recent Advances in Phase Separation Kinetics

19-12-1996	T. Shiota Kyoto University Japan	Nonlinear diffusion equations and image processing
24-12-1996	Alessandra Carbone Univ. of Paris XII France	Making proofs without Modus Ponens: An introduction to the combinatorics and complexity of cut elimination
24-12-1996	F. H. M. Faisal Universitaet Bielefeld Germany	de Broglie-Bohm Formulation of Quantum Mechanics, Quantum Chaos and Breaking of the Time-reversal Symmetry
26-12-1996	Alessandra Carbone Univ. of Paris XII France	Looking from inside and outside
27-12-1996	Akhil Ranjan IIT, Mumbai	Metric foliations of spheres
30-12-1996	W. van der Kallen Universitiet Utrecht, The Netherlands	Constant terms of powers of Laurent polynomials
30-12-1996	Charles Swartz New Mexico State University, USA	The uniform boundedness principle without completeness
3-1-1997	Dinakar Ramakrishnan California Institute of Technology, USA	Determination of elliptic curves upto quadratic twists
3-1-1997	Raghavan Rangarajan Houston Adv. Res. Center, USA	Baryogenesis in the Early Universe
15-1-1997	F. Calogero University of Rome Italy	A solvable many-body problem in the plane

16-1-1997	Jurgen Herzog University of Essen Germany	Gotzmann's theorem on simplicial complexes
21-1-1997	A. Thilagam Northern Territory University, Australia	Dynamics of Excitons in Quantum Wells
22-1-1997	J. Ladik Friedrich Alexander Univ., Germany	Theory of Non-Linear Optical Properties of Polymers.
27-1-1997	Varghese John Syracuse University USA	Quantum geometry of Fluctuating Surfaces
28-1-1997	Probir Roy TIFR, Mumbai	Sharpening signals of low-energy supersymmetry
30-1-1997	V. Lakshmibai Northeastern Univ., USA	Ladder determinantal ideals and Schubert varieties
30-1-1997	Suneeta Vardarajan IMSc	Three-manifold invariants from knot theory
31-1-1997	Z. Belhachmi University of Metz, France	Shape optimal design by homogenization - Review and new applications
3-2-1997	V. Soni NPL, New Delhi	Z tests for QCD
10-2-1997	C. Pandu Rangan IIT, Madras	Randomized Algorithms for Identity Verification
11-2-1997	V. S. Alagar Concordia University, Montreal, Canada	Software Reuse-the role of formalism

11-2-1997	Arundhati Dasgupta IMSc	Hawking Radiation from D-branes Including Back Reaction
12-2-1997	R.Rajaraman JNU	Field theory of Single and Double Layer Quantum Hall Systems
14-2-1997	Alberto Perelli University of Genoa, Italy	Basic theory of Selberg Class
14-2-1997	N. V. Vinodchandran IMSc	Exact learning via Teaching Assistants
14-2-1997	S. Ramanan TIFR, Mumbai	Topics in Algebraic Geometry
17-2-1997	Paul Krasucki Dow Jones Telerate and Brooklyn College, New York, USA	When communicating agents cannot disagree
17-2-1997	Alberto Perelli University of Genoa, Italy	Zeros of functions in Selberg class
19-2-1997	Matthias Brack University of Regensburg, Germany	Periodic Orbits and shell effects in finite fermion systems: Applications to Metal Clusters, Quantum dots and Nuclei.
19-2-1997	S. Ramanan TIFR, Mumbai	Projective structures on Riemann surfaces I
21-2-1997	David Goodings McMaster University, Canada	Semiclassical quantization of integrable and nonintegrable systems using Bogomolny's transfer operator.
21-2-1997	S. Ramanan TIFR, Mumbai	Topics in Algebraic Geometry II

24-2-1997	D. Jana RRI, Bangalore	Diamagnetism in Quantum Bose Systems
25-2-1997	Mitaxi Mehta PRL, Ahmedabad	Convergence properties of the time-dependent canonical perturbation theory
26-2-1997	Ramanan TIFR, Mumbai	Syzygies
27-2-1997	H. Esnault University of Essen Germany	Algebraic differential characters of bundles with connections
28-2-1997	Amitabha Chakrabarti Ecole Polytechnique, Paris, France	Periodic and Quasiperiodic Instantons
28-2-1997	S. Ramanan TIFR, Mumbai	Topics in Algebraic Geometry III
5-3-1997	S. Ramanan TIFR, Mumbai	Projective structures on Riemann surfaces II
6-3-1997	Anil Kumar IISc	Surface and the associated bulk transitions in Multicomponent Liquid Systems
6-3-1997	Pijush Ghosh MRI, Allahabad	Self-dual Gauged Sigma models
7-3-1997	S. Ramanan TIFR, Mumbai	Topics in Algebraic Geometry IV
10-3-1997	P.S. Thiagarajan SPIC Math. Inst.	A Trace Based Expressively Complete Linear Time Temporal Logic

11-3-1997	Raimundo Rocha dos Santos Instituto de Fisica, Brazil	Strongly Correlated Fermions on Superlattices: sm and Superconductivity
12-3-1997	S. Ramanan TIFR, Mumbai	Projective structures on Riemann surfaces III
13-3-1997	Abijit Kar Gupta SINP, Calcutta	Electrical conduction in nonlinear composites: a percolative approach.
13-3-1997	Deshdeep Sahdev IIT, Kanpur	Non-linear Dynamics of Josephson Junction Arrays
14-3-1997	Sujit Sarkar SINP, Calcutta	Superconductivity with different pairing symmetries
17-3-1997	S. Kalyana Rama MRI, Allahabad	Can String Theory Avoid Cosmological Singularities?
18-3-1997	Manas Kumar Sardar Univ of Regensberg, Germany	Parametric Amplication of Radiation Using Josephson Junctions in High Tc materials
20-3-1997	R. Ramanujam IMSc	Introduction to Quantum Computers
20-3-1997	Chandrakumar CLRI, Madras	Spin Computers
24-3-1997	Mahesh Nerurkar Rutgers University USA	Recurrence in dynamical systems
25-3-1997	R. Shankar IMSc	Quantum Mechanics of Coupled two level systems
27-3-1997	David Butler TIFR, Mumbai	Maruyama bundles

2-4-1997	Lokam V. Satyanarayana Univ. of Toronto, Canada	Spectral Methods for Matrix Rigidity with Applications
2-4-1997	J. Pasupathy IISc, Bangalore	PCAC in the nuclear medium
9-4-1997	V. Arvind IMSc	Classical circuit models and Turing machines
10-4-1997	David Butler TIFR, Mumbai	Syzygies
16-4-1997	V. Arvind IMSc	Feasible Computation
16-4-1997	P. M. Mathews Madras University	Modern Geodesy and Geophysical Modelling – An Overview
23-4-1997	N. D. Haridass IMSc	Quantum Computation and Shors Factoring Theorem
23-4-1997	R. Simon IMSc	From Classical Orbits to Semiclassical matrix elements: An unlikely application of geometric phase
25-4-1997	S. Ramakrishna IMSc	Physics of early events in photosynthetic purple bacteria
28-4-1997	R. J. Wilson Open University, England	Let Newton be
30-4-1997	N. D. Haridass IMSc	Quantum Computation and Shors Factoring Theorem
2-5-1997	Antoni Lozano UPC, Barcelona Spain	The complexity of algorithms on succinct input representations.

7-5-1997	Rossen Dandoloff Université de Cergy-Pontoise, Paris, France.	Topological solitons and geometrical frustration
7-5-1997	S. Srinivasa Rao IMSc	Approximation Algorithms for the Maximum Satisfiability Problem
12-5-1997	Prashant Gade JNC, Bangalore	Stochastic Resonance in Maps and Coupled Map Lattices
14-5-1997	M. MukandaRao IIT, Madras	Monitoring of Brain events using optical sensors
16-5-1997	G. Manoj IMSc	Modulated phases in two component Fluid Membranes
19-5-1997	A R Prasanna PRL, Ahmedabad	Inertial Forces in General Relativity
21-5-1997	Balram Rai Univ. & Research Centre of Crete, Greece	String-like Solitons in two-Higgs-Doublet Extension of Standard Model
29-5-1997	P. B. Sunil Kumar IMSc	Dynamics of Fluid Membranes
5-6-1997	K.T. Arasu Wright State Univ. USA	On Hadamard matrices
11-6-1997	Roman Tomaschitz Univ. of the Witwatersrand, Johannesburg, SA	Chaos and Topological Evolution in Cosmology
12-6-1997	K. Soundara Rajan Princeton University USA	Volterra Equations and Quadratic Reciprocity

18-6-1997	Kamales Kar SINP, Calcutta	Nuclear structure for Gallium detectors of solar neutrinos
25-6-1997	Madhavan Varadarajan RRI, Bangalore	Quantum Fields at Any Time
26-6-1997	C. S. Rajan TIFR, Mumbai	The automorphism group of X(11) in characteristic 3 is M_{11}
30-6-1997	V. Kamakoti IISc, Bangalore	Randomized algorithms for proximity problems
17-7-1997	Mohan Nair Glasgow University, U.K.	Primes, Squares and Fermat
18-7-1997	Mohan Nair Glasgow University UK	Extremal values of $\Delta(x,N) = \sum_{n\leq xN,(n,N)=1} 1 - x\phi(N)$
21-7-1997	Peter Sin University of Florida USA	The ranks of some incidence matrices
29-7-1997	Sinnou David University of Paris France	Heights of Abelian Varieties
30-7-1997	A. P. Balachandran Syracuse University USA	Topological Quantization and Quantum Groups
31-7-1997	H. Lange Universitat Erlangen Germany	Complex Tori

2.5 Visitors

Name	Affiliation	Period of Visit
N. Sivaramakrishnan	Central Michigan University, USA	2.1.96 to 10.6.96
Ferdinando Mancini	University of Salero, Italy	6.4.96 to 10.4.96
V Srinivasan	Univ. of Hyderabad	6.4.96 to 10.4.96
Ashish Chainani	Tohoku University, Japan	7.4.96 to 9.4.96
Dileep Jatkar	MRI Allahabad	1.5.96 to 31.5.96
Rama Mishra	MRI Allahabad	10.5.96 to 18.5.96
Daksh Lohiya	University of Delhi	5.6.96 to 7.6.96
Ambar Sengupta	Louisiana State University, USA	25.6.96 to 28.6.96
M Muthukumar	Univ. of Mass. Amherst, USA	24.6.96 to 26.7.96
Jeeva S Anandan	University of South Carolina, USA	18.7.96 to 12.8.96

S.P. Inamdar	T.I.F.R. Mumbai	22.7.96 to 28.7.96
K. Srinivas	TIFR Mumbai	31.7.96 to 4..8.96
K.B. Sinha	ISI Bangalore	20.8.96 to 22.8.96
Reuben Rabi	Kings' College, U.K.	16.8.96 to 31.8.96
Balachandran Sathiapalan	Penn State University USA	26.8.96 to 30.8.96
B Halperin	Harvard University USA	18.9.96 to 23.9.96
Padmanabhan Krishnan	University of Canterbury, New Zealand	23.9.96 to 5.10.96
Amol Dighe	Enrico Fermi Inst. University of Chicago USA	24.9.96 to 29.9.96
Srimanth Raghavan	Univ. of New Mexico, USA, and ICTP, Italy	16.10.96 to 18.10.96
P.S. Subramanian	TIFR Mumbai	27.10.96 to 31.10.96
Rudra Prakash Malik	JINR, Dubna, Russia	7.11.96 to 11.11.96
J S Prakash	Inst. of Physics, Bhubaneswar	4.12.96 to 19.2.97

T. Shiota	Kyoto University Japan	7.12.96 to 25.12.96
Jan Amjorn	Niels Bohr Inst. Denmark	7.12.96 to 11.12.96
Ian Munro	Univ. of Waterloo, Canada	8.12.96 to 15.12.96
Tobias Nipkow	Techniche Univ., Muenchen, Germany	14.12.96 to 17.12.96
Ron Van Der Meyden	Sydney Univ. of Tech. Australia	14.12.96 to 17.12.96
Gilbert Ndjatou	City Univ. of New York, USA	16.12.96 to 17.12.96
Dinakar Ramakrishnan	Caltech, USA	16.12.96 to 5.1.97
M. Agrawal	IIT Kanpur	20.12.96 to 24.12.96
P.S Subramanian	TIFR Mumbai	21.12.96 to 31.12.96
Eric Allender	Rutgers University, U.S.A.	21.12.96 to 10.1.97
Alessandra Carbone	University of Paris, France	21.12.96 to 27.12.96

Vaughan Pratt	Stanford University USA	21.12.96 to 22.12.96
A. Ranjan	IIT Mumbai	24.12.96 to 31.12.96
F H M Faisal	Univ. of Bielefeld, Germany	24.12.96 to 27.12.97
W. Van der Kallen	University of Utrecht Netherlands	26.12.96 to 4.1.97
V. Vinay	IISc, Bangalore	25.12.96 to 2.1.97
C. Swartz	New Mexico State Univ., USA	29.12.96 to 2.1.97
Raghavan Rangarajan	Houston Adv. Res. Center, USA	2.1.97 to 3.1.97
A Thilagam	Northern Territory University of Australia	11.1.97. to 24.1.97
Bo Lovschall	Univ. of Copenhagen Denmark	17.1.97 to 22.6.97
Matthias Brack	Univ. of Regensberg Germany	18.1.97 to 24.2.97

J Ladik	Institute of Theoretical Chemistry Friendrich Alexander, Germany	21.1.97 to 22.1.97
Esnault Helona	Universität Asser, Germany	22.1.97 to 1.3.97
Eric Allender	Rutgers University, USA	27.1.97 to 27.2.97
David A Goodings	McMaster Univ., Canada	9.2.97 to 10.3.97
Chanchal Kumar	TIFR Mumbai	11.2.97 to 12.3.97
S. Ramanan	TIFR Mumbai	11.2.97 to 13.3.97
Alberto Perelli	University of Genoa Italy	13.2.97 to 18.2.97
Manisha Kulkarni	MRI Alllahabad	14.2.97 to 4.4.97
P. Weil	Univ. Paris 7 France	14.2.97 to 31.8.97
A Lozano	Universitat Politecnica Catalunya, Spain	16.2.97 to 13.8.97
E. Viehweg	University of Essen Germany	22.2.97 to 1.3.97

H. Esnault	University of Essen Germany	22.2..97 to 1.3.97
T.N. Venkataramana	TIFR Mumbai	26.2.97 to 11.3.97
Amitabha Chakrabarti	Ecole Polytechnique, France	27.2.97 to 2.3.97
S Balasubramanian	Madurai Kamaraj University	27.2.97 to 4.3.97
Ramakant	S N Bose Center for Basic Sciences, Calcutta	2.3.97 to 11.3.97
Anil Kumar	IISc, Bangalore	4.3.97 to 5.3.97
Mahesh Nerurkar	Rutgers University USA	4.3.97 to 25.3.97
Kalyan Chakraborty	MRI Allahabad	5.3.97 to 31.3.97
J V Barth	Ecole Polytechnique Federale de Lausanne	7.3.97 to 8.3.97
Raimundo Dos Santos	Instituto de Fisica Universidade Federal Fluminense, France	7.3.97 to 12.3.97
B. Ramakrishnan	MRI Allahabad	12.3.97 to 31.3.97

S.D. Adhikari	MRI Allahabad	12.3.97 to 31.3.97
Sujit Sarkar	SINP, Calcutta	13.3.97 to 15.3.97
Manas Sardar	Univ. of Regenburg, Germany	4.3.97 to 20.3.97
Abhijir Kar Gupta	SINP, Calcutta	13.3.97 to 28.3.97
S Kalyana Rama	MRI, Allahabad	15.3.97 to 29.3.97
David Butler	TIFR Mumbai	17.3.97 to 17.4.97
J. Pasupathy	IISc, Bangalore	29.3.97 to 5.4.97
L.V. Satyanarayana	University of Toronto Canada	31.3.97 to 3.4.97
Myrzakulov Ratlay	High Energy Phys. Inst., National Acad. of Science of Kozakstan, Alma Ata	1.4.97 to 2.4.97
Rossen Dandoloff	Univ. de Cergy-Pontoise, France.	9.4.97 to 19.4.97
S. Umasankar	IIT, Mumbai	13.4.97 to 15.4.97
C.S. Rajan	TIFR Mumbai	14.4.97 to 16.5.97

P.P. Divakaran	TIFR Mumbai	16.4.97 to 16.5.97
Robin J Wilson	Open University, Milton Keynes, UK	26.4.97 to 29.4.97
R.P. Malik	BLTP, JINR, Dubna, Moscow, Russia	30.4.97 to 9.6.97
Balram Rai	University of Crete Heraklion, Greece.	3.5.97 to 25.5.97
B. Ramakrishnan	MRI Allahabad	9.5.97 to 30.5.97
S.D. Adhikari	MRI Allahabad	9.5.97 to 30.5.97
A.R. Prasanna	Theory Division, PRL, Allahabad	15.5.97 to 21.5.97
S. Ponnusamy	IIT, Guwahati	21.5.97 to 24.6.97
K. Soundararajan	Princeton Univ., USA	23.5.97 to 8.7.97
K.T. Arasu	Wright State Univ. USA	2.6.97 to 9.6.97
Roman Tomaschitz	University of the Wifwaterronol, Johannesburg, SA	10.6.97 to 15.6.97
Madhavan Varadarajan	RRI, Bangalore	22.6.97 to 16.7.97

Mohan Nair	Univ. of Glasgow UK	10.7.97 - 19.7.97
Dida Midekso	Addis Ababa Univ Ethiopia	17.7.97 - 9.9.97
Marti Sanchez	Univ. Politechnica Catalunya Barcelona, Spain	18.7.97 - 15.10.97
Peter Sin	Univ. of Florida USA	20.7.97 - 21.7.97
N.R. Nandakumar	Delaware State Univ., Dover, USA	23.7.97 - 26.7.97
R.K. Bhaduri	McMaster Univ. Canada	27.7.97 - 10.8.97
K.S. Viswanathan	Simon Fraser Univ., Canada	27.7.97 - 20.8.97
A.P. Balachandran	Syracuse Univ. USA	28.7.97 - 1.8.97

2.6 Student Programme

2.6.1 Institute JRFs

The institute selects junior research fellows to work towards their PhD every year in the areas Mathematics, Physics and Theoretical Computer Science. These students are selected after a nationwide entrance test followed by an interview at the Insitute. During the first year, these students go through rigorous course work. Then they register for their PhD usually with the Madras University. Exceptionally bright Bachelor's students are also selected in this process. These students, before registering for PhD, go through a two year M.Sc (by research) programme awarded by the Anna University.

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The following student of the institute was awarded Ph.D. degree by the Madras University last year ('96).

Name	**Amora Nongkynrih**
Discipline	Mathematics
Title	On Primitive Roots
Guide	R. Balasubramanian.

****

The following student has completed all the requirements for a Ph.D.

Name	**P. Ramadevi**
Discipline	Physics
Title	Cherns-Simons theory as a theory of knots and links
Guide	T. R. Govindarajan.

****

The following Ph.D. theses have been submitted to Madras University:

Name	**S.A. Khan**
Discipline	Physics
Title	Quantum theory of charged-particle beam optics
Guide	R. Jagannathan.

Name	**Srinath Cheluvaraja**
Discipline	Physics
Title	Finite temperature phase transition in non-abelian gauge theories
Guide	H.S. Sharatchandra

Name	**D. Shubashree**
Discipline	Physics
Title	Field Theory of Frustrated Antiferromagnets: an approach to the Kagome Lattice model
Guide	R. Shankar

****

The following students of the institute were awarded the M.Sc. (by research) degree by the Anna University in September 1996.

Mathematics

Name	**D. Surya Ramana**
Title	A theorem of Cowsik and Nori
Guide	Sathya Mandal

Physics

Name	**Jayajit Das**
Title	Growth without coalescence in Martensites
Guide	Madan Rao

Name	**Arundhathi Dasgupta**
Title	Fermions in black hole space-time: Hawking radiation and back reaction
Guide	Parthasarathi Majumdar

Name	**Pushan Majumdar**
Title	Some aspects of constraints in Yang-Mills theory
Guide	H.S. Sharatchandra

Name	**Subhasis Sinha**
Title	Application of Thomas-Fermi method to quantum dot systems
Guide	M.V.N. Murthy

Name	**Dutta Sridhar Babu**
Title	Skyrmions in Quantum Hall Systems
Guide	R. Shankar

Theoretical Computer Science

Name	**P. Madhusudan**
Title	On the Fly verification algorithm for linear time temporal logic
Guide	Kamal Lodaya

The following students of the institute have successfully completed the M.Sc. (by research) program of the Anna University in May 1997.

Name	**G. Manoj**
Discipline	Physics
Title	Modulated phases in two component fluid membranes
Guide	Madan Rao
Name	**Ronojoy Adhikari**
Discipline	Physics
Title	Some aspects of CP violation
Guide	N.D. Hari Dass
Name	**S. Srinivasa Rao**
Discipline	Theoretical Computer Science
Title	A survey of approximation algorithms for the maximum satisfiability problem
Guide	Venkatesh Raman

****

The following lecture courses were offered during the last academic year.

Course Title	**Period**	**Lecturer**
Mathematics		
Algebraic Geometry	Sep 96 - Apr 97	D.S. Nagaraj
Riemann Surfaces	Nov 96 - May 97	S.P. Inamdar
Physics		
Classical Mechanics	Aug - Dec 96	M. V. N. Murthy
Classical Electromagnetism	Aug - Dec 96	Tapash Chakraborty
Quantum Mechanics	Aug - Dec 96	N.D. Hari Dass
Mathematical Methods	Aug - Dec 96	R. Simon
Advanced Quantum Field Theory	Aug - Dec 96	Parthasarathi Majumdar
Advanced Particle Physics	Aug - Dec 96	Romesh Kaul
Advanced Condensed Matter Physics	Aug - Dec 96	R. Shankar
General Relativity	Aug - Dec 96	Ramesh Anishetty

Course Title	Period	Lecturer
Statistical Physics	Jan - May 97	H. S. Sharatchandra
Quantum Field Theory	Jan - May 97	Rahul Basu
Introductory Condensed Matter Physics	Jan - May 97	R. Sridhar
Introductory Particle Physics	Jan - May 97	T. Jayaraman
Advanced Statistical Mechanics	Jan - May 97	Madan Rao
Nonlinear Dynamics	Jan - May 97	Sudeshna Sinha
M-theory	March 97	N.D. Hari Dass
Theoretical Computer Science		
Complexity Theory	Aug - Dec 96	V. Arvind
Modal and Temporal Logics	Aug - Dec 96	R. Ramanujam
Parallel Algorithms	Aug - Dec 96	Venkatesh Raman
Automata, Logic and Circuit Complexity	Sept - Nov 96	Kamal Lodaya
Topics in Complexity Theory	February 97	Eric Allender (Rutgers Univ, USA)
Products of Automata	July 97	Pascal Weil (LIAFA, Univ. of Paris VII)

2.6.2 Summer Students

Every summer, a small number of students from various institutes/universities come to our institute and work on some research projects with some faculty member. During the last two summers, the following students visited our institute.

Student	Period	Faculty
Mathematics		
P.N. Neelima Ethiraj College Madras	30.4.97 - 29.6.97	V.S. Sunder
N. Hariharan Bangalore Univ.	May-July 1997	R. Balasubramanian

Student	Period	Faculty
Physics		
Geetanjali Gauba Delhi University	May 1996	T.R. Govindarajan
Rohit Dhamanker IIT, Kanpur	26.5.96 - 19.7.96	Radha Balakrishnan
Budhapriya Chakraborty JNU, Delhi	4.6.96 - 4.7.97	T.R. Govindarajan
P. Padma Ram IIT Madras	5.6.97 - 5.7.97	Purusattam Ray
K. Madhusudhan IIT Madras	12.6.97 - 12.7.97	T.R. Govindarajan
Tirthabir Biswas IIT, Kanpur	19.6.96 - 30.7.96	R. Ramachandran
Theoretical Computer Science		
T V Prasanna IIT Kanpur	May - June 1996	R Ramanujam
Anirban Dasgupta IIT Kharagpur	14.5.97 - 1.7.97	Meena Mahajan
Kumar Saurabh IIT Kharagpur	14.5.97 - 1.7.97	Venkatesh Raman

2.6.3 NURTURE Programme

NBHM Nurture Programme, 1995-96

Every year, the National Board for Higher Mathematics trains a certain number of highly talented students for the International Mathematical Olympiad (and a team of six students is chosen out of this group to represent India at the Olympiad). These mathematically gifted students soon lose contact with higher mathematics as they go on to pursue professional courses. In order to retain their contact with mathematics, and to nurture their talents in that direction, the National Board for Higher Mathematics, has thought of a scheme wherein these students are placed under the charge of a mathematically active faculty in some prestigious institution and follow some courses in higher mathematics guided by this

faculty by correspondence. At the end of the academic year, the students meet the Faculty for a Contact Programme lasting three to four weeks, where they are evaluated and guided further. This interaction of the Faculty and each group is meant to last four years.

From the group trained for the Olympiad in 1995, the National Board of Higher Mathematics selected 15 students to participate in its Nurture Programme based at the Institute of Mathematical Sciences, Chennai, and 14 of them accepted. Two other students later requested participation and this was accorded to them after getting the approval of the Chairman, NBHM.

These 16 students were put under the charge of a Faculty consisting of V. Balaji (SPIC Mathematics Institute-SMI), R. Balasubramanian (IMSc.), S. Kesavan (IMSc., Convener), K.N. Raghavan (SMI), P. Sankaran (SMI), and V.S. Sunder (IMSc.).

The course work assigned for the first year, *i.e.* 1995-96, consisted of Analysis (based on the first 7 chapters of Rudin's *Principles of Mathematical Analysis*), Algebra (based on the first 7 chapters of Artin's *Algebra*) and Linear Algebra (based on notes supplied by V.S. Sunder and on other books including Artin *op. cit.*). Two sets of exercises were sent to the students to solve and return to the Faculty for evaluation.

A Contact Programme was conducted at the Institute of Mathematical Sciences, Chennai from Monday, June 17 to Friday, July 5, 1996. All the 16 participants attended the same. The students were lodged in the Guest House of the Institute of Mathematical Sciences. They were given library and other facilities.

The students followed three 90 - minute lectures per day for five days a week. The first three days of the Programme was devoted to a review of the material assigned to the students for self-study during the year. This was followed by lecture courses on Multilinear Algebra, Finite Groups, Rings and Fields, Set Theory, Metric Topology, Calculus on Normed Linear Spaces and Measure Theory. In addition a few special lectures were arranged on topics of interest *viz.* Ramanujan, Algebraic Curves and Riemann Surfaces.

The following is the list of lecturers and the topics taught by them:

Revision

V. S. Sunder	:	Linear Algebra
S. Kesavan	:	Analysis
V. Balaji		Algebra
P. Sankaran	:	Algebra
K. N. Raghavan		Algebra

Courses

K. N. Raghavan	:	Multilinear Algebra
P. Sankaran	:	Rings and Fields
V. Balaji	:	Groups
V. S. Sunder	:	Set Theory
R. Balasubramanian	:	Metric Topology
S. Kesavan	:	Calculus of Several Variables
V. S. Sunder	:	Measure Theory

Special Lectures

R. Balasubramanian	:	Ramanujan
S. Nag (IMSc)	:	Riemann Surfaces
K. Viswanath (SPIC)	:	Algebraic Curves

To evaluate the students, a written test was conducted in Algebra, Analysis and Linear Algebra. On the last two days, the students were individually interviewed by the Faculty for further assessment.

Based on the inputs provided by the written exercises, written tests and the interviews, as well as the interaction with the students during the period of the Contact Programme, the Faculty recommended that 13 of the 16 participants be continued in the Nurture Programme. These students were assigned further topics for self-study and will be participating in the contact programme to be held in June 1997 (cf. the following report for details of this.)

NBHM Nurture Programme, 1996-97

The Contact Programme at the end of the Second Year of the NBHM Nurture Programme 1995-96 was held at the Institute of Mathematical Sciences, Chennai, from Monday, June 16 to Saturday, July 5, 1997. Of the 16 students who attended the Programme last year, 13 were reinvited this year and all of them attended the Programme.

These 13 students continued to be under the charge of the Faculty comprising of V. Balaji (SPIC Mathematics Institute-SMI), R. Balasubramanian (IMSc.), S. Kesavan (IMSc., Convener), K. N. Raghavan (SMI), P. Sankaran (SMI), and V. S. Sunder (IMSc.)

The course work assigned for the second year, *i.e.* 1996-97, consisted of Measure Theory (based on the lecture notes by K. Chandrasekaran, published in the TRIM Series and on the book *Real Analysis* by H. L. Royden), Algebra (based on the chapters 8, 9 and 10 of Artin's *Algebra*) and Topology and Functional Analysis (based on the book *Introduction to Topology and Modern Analysis* by G. F. Simmons). Exercises were sent in each of these subjects to the students to solve and return to the Faculty for evaluation.

During the Contact Programme, these subjects were thoroughly reviewed via lectures by the Faculty members. These lectures went beyond the material prescribed to discuss more advanced topics in these subjects. In addition, introductory lecture courses on Algebraic Number Theory, Algebraic Topology and Complex Analysis were arranged.

To evaluate the students, written tests were conducted in Topology and Functional Analysis, Algebra and Measure Theory. On the last two days,the students were individually interviewed by the Faculty for further assessment.

2.6.4 Summer School in TCS

The TCS group at IMSc organized a Summer School from May 19 to June 6, 1997. The school was intended for undergraduate and graduate students who have already had a reasonable exposure to computer science. The purpose of this school was to provide a basic understanding of some of the theoretical foundations of computer science. The participation was restricted to students from institutes and colleges in Chennai.

Broadly speaking, the topics introduced were: (a) logic and formal methods in computing (a course of 8 lectures by R. Ramanujam and Anil Seth), (b) applied combinatorics (a course of 4 lectures by V. Arvind) (c) automata theory and formal languages (a course of 8 lectures by Kamal Lodaya and Meena Mahajan), and (d) algorithms and data structures (a course of 10 lectures by V. Arvind and Venkatesh Raman). On the last day there was a special lecture on *Undecidability* by Kamal Lodaya and on *NP-completeness* by Meena Mahajan.

The summer school turned out to be a satisfying teaching experience for the TCS group. There were 22 participants in all. At the end of the three weeks of intensive lecturing, discussions and problem-solving (which was a new experience for the participants), there was finally a well-motivated group of about 10 participants who wished to pursue theoretical computer science for further studies. Several participants will continue to maintain contact with IMSc. In particular, some of them are keen to do their M.Sc projects with members of the TCS group.

2.6.5 XII SERC School on High Energy Physics: Part I

This school was held at IMSc from November 4, 1996 to November 30, 1996. About 20 students from various research institutes and universities attended the School. There were three main courses. Prof G. Rajasekaran gave 18 lectures on *Gauge Theory and Standard Model* assisted by Drs. Rahul Sinha and B. Ananthanarayan in the tutorial and discussion sessions. Prof R. Ramachandran gave a series of 12 lectures on *Gravitation* assisted by Dr. G. Date in conducting the tutorial and discussion sessions. Dr. S. Govindarajan of IIT Madras taught the course on *Mathematical Methods: Group theory, Supersymmetry, and Differential Geometry* and he was assisted by Dr. L. Chandar in the tutorial and discussion sessions.

2.6.6 The National Science Day

The National Science Day was celebrated at this institute on the 28th of February, 1997 to commemorate the birth anniversary of Prof. C.V. Raman. The institute viewed this as an oppurtunity to organise programmes that would bring undergraduate and begining post-graduate science students in Chennai in contact with the research activities and the general facilities at this institute. Towards this end invitations for participation were extended to college students in and around Chennai. About a hundred students pursuing various branches of science responded.

The programmes began with a set of lectures outlining the general themes of research persued by the faculty and the students of this institute in the areas of Physics, Mathematics and Theoretical Computer Science.

After these lectures the participants were taken around the institute and shown the computer and library facilities available with the institute. The emphasis here was to let the participants know what facilities were available to the general public.

The highpoint in the celebrations was a science quiz organised for the participants. The quiz was at the undergraduate science level and the paticipants were quizzed on a broad range

of topics from biology to mathematics. The winners were awarded prizes that included a year's free subscription to the science magazine *Resonance*.

The celebrations ended with a lecture by Prof. G.Baskaran of this institute who also distributed the prizes to the winners of the quiz.

2.6.7 The M.T. & T.S. Programme

This is an ongoing programme that is conducted by the National Board for Higher Mathematics. (The acronym stands for 'Mathematics Training and Talent Search Programme'.) Students with an aptitude for mathematics are selected from all over India and a four week contact programme is held each year. Members of the mathematics group of the IMSc have always been active participants in this programme.

Thus, in the 1996 programme, which was conducted at the Fergusson College, Pune, M. Krishna and V.S. Sunder played key roles in this programme, both as organisers and as 'resource persons'.

The 1997 programme, which was held at IIT, Chennai, was organised by S. Kumaresan (Bombay Univ.), S.H. Kulkarni (IIT, Chennai), M. Krishna (IMSc) and I.K. Rana (IIT, Mumbai). The resource persons for this year's programme included S.P. Inamdar, Vijay Kodiyalam, M. Krishna, D.S. Nagaraj, and K. Srinivas from this institute.

2.7 Visits to other Institutions

(including conference participation and lectures by institute members)

Arvind, V.:

Attended the Foundations of Software Technology and Theoretical Computer Science Conference in Hyerabad, during December 16–19, 1996. Also, chaired a technical session in the same conference.

Visited Universität Ulm, Abteilung Theoretische Informatik, Ulm, Germany during the period June 23 – July 6, 1997.

Presented a contributed paper titled *A nonadaptive NC checker for permutation group intersection* at 12^{th} annual IEEE Conference on Computaional Complexity, held at Ulm, Germany from June 24 – 27, 1997.

Delivered a couple of lectures on *Matching Algorithms* at Xavier's College, Palayamkottai, organized by Manonmaniam Sundaranar University, Tirunelveli on March 8th, 1997.

Balakrishnan, Radha:

Visited ICTP, Trieste, Italy during the period September 5th to 19th, 1996.

Visited Los Alamos National Laboratory, Los Alamos, U.S.A , during the period September 22, 1996 to December 5, 1996.

Visited the Department of Applied Mathematics, University of Colorado, Boulder , Colorado, U.S.A, from October 21 to October 28, 1996, and gave a Colloquium on *Nonlinearity and Geometry: Some Applications in Physics*.

Participated in the International Conference on Dynamical Systems held at I.I.Sc., Bangalore from January 10 -14, 1997, and lectured on *Geometry and nonlinear evolution equations* on January 13, 1997.

Lectured on *Connection between nonlinearity and geometry* at the Materials Science Division, IGCAR, Kalpakkam on April 4th, 1997.

Lectured on *Geometry and nonlinearity* at the Liquid Crystals Group, Raman Research Institute, Bangalore, on April 23rd, 1997.

Balasubramanian, R.:

Visited Fukuoka University, Japan for two weeks during May 1996.

Visited National University of Singapore in May 1996.

Attended the Conference in Number Theory in Kyoto in May 1996.

Delivered the Eighth Ramanujan Endowment Lecture in Anna University, Madras, on 10th Jan 1997.

Delivered a special lecture in the Workshop on Essential Mathematics for Engineering held in IIT, Madras.

Delivered six lectures on *Elliptic curves, Modular forms and Cryptology* in the Ramanujan Mathematical Society meeting held in Bhopal.

Baskaran, G.:

Spent a term (January - June 1996) at the Institute for Advanced studies at Princeton.

Visited the Department of Physics, Yale University during April 96 and gave a talk on *Anomalous properties of composite fermions in the fractional quantum Hall fluid.*

Visited the Department of Physics, University of Chicago, Chicago during April 1996 and gave a talk on the *Quantum Hall fluid at half filling.*

Visited the Department of Physics, University of Virginia, Charlotsville, VA during May 96 and gave a talk on *Interlayer pair tunneling mechanism of superconductivity.*

Was one of the organizers of a workshop on *Perturbative methods in strongly correlated fermi systems*, held at the International Center for Condensed Matter Physics at Brasilia, Brazil during the first week of July 1996; also gave a talk on *The issue of non fermi liquids in 2 dimensions* as also the workshop summary talk.

Was one of the organizers of the Summer Workshop in Condensed Matter Physics at the International Center for Theoretical Physics, Trieste, 1996 as well as the Mini Workshop on Strongly Correlated Electron Systems (in July 96).

Visited the Physics Department of Princeton University, USA, from 1st August 1996 till 31st July 1997; and gave two seminars during this stay, on *Non fermi liquid behavior and p-wave superconductivity in* Sr_2RuO_4, and *An approach to composite fermions within the lowest Landau level.*

Visited the Department of Physics, University of Illinois-Urbana Champaign, during Sept 96 and gave a talk on *The failure of fermi liquid theory in 2 dimensions.*

Visited the Department of Physics, University of Cincinatti, Cincinatti during October 96 and gave two talks, on *Nature of the non-fermi liquid state* and *Anomalous properties of quantum Hall fluid at half filling.*

Visited the Department of Physics, Rutgers University, Rutgers, NJ during December 1996 and gave a talk on *The strange composite fermion at half filled quantum Hall fluid.*

Attended the Mid-Year Meeting of the Indian National Science Academy at New Delhi, during March 1997.

Visited the Department of Theoretical Physics at E T H, Zurich during April 1997 and gave a talk on *Non fermi liquid behavior and p-wave superconductivity in* Sr_2RuO_4.

Visited the Department of Theoretical Physics at the Brookhaven National Laboratory, Long Island during May 97 and gave a talk on *P-wave superconductivity in* Sr_2Ru0_4.

Was one of the organizers of the Summer Workshop in Condensed Matter Physics as well as the 'Mini Workshop on Open problems in Strongly Correlated Electron Systems' at ICTP, Trieste, Italy (in July 97).

Basu, Rahul:

Attended the Summer School in High Energy Physics, at ICTP, Trieste in July 1996.

Attended the 28th International Conference in High Energy Physics, Warsaw, Poland, 24th July 1996 - 31st July 1996.

Attended the SUJAYATA - 50th Anniversary celebration of TIFR - satellite conference on Particles and Fields and also the main SUJAYATA meeting in Sep 1996.

Attended the XII DAE Symposium of High Energy Physics, Guwahati, Dec 1996; and gave a lecture on *HERA Physics.*

Gave a course of 10 lectures on *Deep Inelastic Scattering* at the SERC school held at CTS, IISc, Bangalore from 24th Feb 1997 to 8th Mar 1997.

Made TPSC visits to TIFR, Bombay, PRL, Ahmedabad, MRI, Allahabad and Physics Dept., Delhi University during the period 16th March 1997 - 2nd April 1997, and delivered seminars on *Low x QCD and application of double scaling to semi-inclusive processes at HERA* at the four centres mentioned above.

Bhattacharyya, Tirthankar:

Gave a talk on *Commuting compact operators* at the Indian Institute of Science on 7th April 1997.

Das, Saurya:

Visited the International Centre for Theoretical Physics to attend the Spring School and for carrying out research in high energy physics, for 6 weeks in April-May 1996; gave lectures entitled *Eikonal as a probe to Planck scale physics* during this visit, as well as during a three day visit to the University of Pisa in April 1996.

Attended the Puri Workshop on Frontiers in Field Theory and String Theory (12-21 December, 1996), and gave a talk titled *High Energy Effects on D-Brane and Black Hole Emission Rates*.

Attended the SUJAYATA TIFR Golden Jubilee Symposium on Theoretical, Physics, Mumbai, September 2nd - 7th, 1996.

Gave a talk at Presidency College, Calcutta on 21st April 1997 titled *Thermodynamics with Black Holes*.

Gave a talk at the Relativity and Cosmology Research Centre, Jadavpur University on 22nd April, 1997 titled *Internal structure of black holes*.

Dasgupta, Arundhati:

Attended the "Workshop on Frontiers in Field Theory, Quantum Gravity and String Theory" held at Puri, India from 11th to 21st December, 1996.

Attended the XII SERC School in Theoretical High Energy Physics, at CTS, Bangalore, India, from 17th February to 8th March, 1997.

Attended the "Trieste Conference in Duality Symmetries in String Theory II", held at ICTP, Trieste, Italy during 2nd-4th April 1997.

Attended the "Spring School in Gauge Theory and Quantum Gravity" ICTP, Trieste from the period 7th-12th April, 1997.

Visited University of Pisa, Italy from the period 14th April to 16th April, and gave a talk titled *High Energy Effects on D-Brane and Black Hole Emission rates*.

Visited ICTP, Trieste, Italy from 17th April to 30th April, 1997, and gave a talk titled titled *High Energy Effects on D-Brane and Black Hole Emission rates*.

Govindarajan, T.R.:

Visited the High Energy Physics Group, Syracuse University, during Sept 96-March 97.

Gave a course of lectures on *D-Branes* in Syracuse University during Sept-Dec 1996.

Gave a seminar on *Skyrmions in Quantum Hall systems* at Syracuse University on 13th November 1996.

Gave a Colloquim on *Chern Simons theory as a theory of knots and links* at Rochester University, Physics and Maths Dept, 31st Jan 1997.

Visited the Physics Dept, McMaster University, Hamilton, Canada. during 1st Feb- 5 Feb 97, and gave a seminar on *Quantum hall skyrmions.*

Lectured on *2+1 d Black hole and Chern Simons theory*, Syracuse University, on 24th Feb 97.

Gave a Colloquim on *Physics and Knots* at Syracuse University, on 26th Feb 1997.

Visited Trinity College, Dublin University, Dublin, Ireland during 5th March -11th March 1997, and gave a lecture on *2+1 d Black hole and Chern Simons theory*, on 11th March 97.

Conducted a set of tutorials in the SERC School at Chandigarh from 15th - 28th April 1996.

Hari Dass, N.D.:

Visited the National Physical Laboratory, New Delhi, in the first week of April, 1996.

Visited the Physics Department,University of Mysore, during 5th May to 5th June, 1997.

Attended the Tata Institute Golden Jubilee Workshop on Foundations of Quantum Theory, and lectured on *Bohm-Aharonov effect and QED without Vector-potentials*, on 10th September 1996.

Attended the Golden Jubilee Workshop at the Physical Research Laboratory,Ahmedabad, and lectured on *Status of Quantum Gravity* on 10th December 1996.

Attended the Puri Workshop on Strings and Quantum Gravity, and lectured on *Finite Size Effects in $d = 2$ Quantum Gravity* on 13th December 1996.

Inamdar, S.P.:

Gave a course of three lectures on *Differential Equations* and a course of two lectures on

Combinatorics , as part of a programme conducted at the Mylapore Children's Club Madras, during the period 12/5/97 to 17/5/97.

Gave a course of 12 lectures on *Metric Spaces* at the MTTS programme conducted by the NBHM at IIT, Madras, during the period 22/5/97 to 17/6/97.

Jagannathan, R.:

Participated in SPIN96, the 12th International Symposium on High Energy Spin Physics - 1996, held at the Free University of Amsterdam, The Netherlands, during September 10-14, 1996 and presented a poster on *Quantum mechanics of accelerator optics : Case of the Dirac particle* authored by M. Conte, R. Jagannathan, S. A. Khan and M. Pusterla.

Visited the Department of Applied Mathematics & Computer Science, University of Ghent, Ghent, Belgium, during September 5-9 and September 15 - October 8, 1996.

Visited DESY, Hamburg, Germany, during October 9-11, 1996.

Gave a seminar on *Beam optics of the Dirac particle* at the Physikalisches Institute, Universität Bonn, Germany, on 14/10/1996.

Visited ICTP, Trieste, Italy, during October 15 - November 13, 1996.

Participated for the first two days of the International Conference on Dynamical Systems, held at Indian Institute of Science, Bangalore, during January 10-15, 1997, and gave a talk on *Beam optics of the Dirac particle* on 10/01/1997.

Jayaraman, T.

Visited SISSA at Trieste, Italy during the period 1st Feb. 1996 to 31st July, 1996, and delivered a set of 15 lectures on *Solitonic solutions in string theory and D-branes.*

Attended the ICTP Spring School on Superstring Theory and the ICTP Summer Workshop in 1996.

Attended 'Sujayatha', the TIFR Golden Jubilee Symposium in Theoretical Physics, Sept. 1996.

Attended the Workshop on Strings, Fields and Quantum Gravity held at Puri, in Dec. 1996, and gave a talk on *D-branes and the Conifold Singularity.*

Kesavan, S.:

Attended the Symposium on Finite Element Technology in Indian Industry, I.I.T., Madras,

June 26 - 27, 1996, and lectured on *Mathematics of the Finite Element Method*.

Gave a lecture on *Isoperimetric Inequalities*, at the Department of Mathematics, R.D. University, Jabalpur, on July 24th, 1996.

Attended the International Conference on Nonlinear Differential Equations and Applications, TIFR Centre, Bangalore, August 19 - 23, 1996 (A Golden Jubilee Event), and gave a lecture on *Symmetry of Solutions of an Elliptic System via Isoperimetric Inequalities*.

Visited Université de Metz, Metz, France from September 1st to October 20th, 1996, to collaborate with Prof. J. Saint Jean Paulin; gave a lecture on *Symétrie des Solutions d'un Système Elliptique Nonlinéaire*, on October 3rd, 1996.

Attended the International Conference on Functional Analysis with Applications, at Aligarh Muslim University, Aligarh, during December 16 - 19, 1996.

Khan, S.A.:

Participated in the Young Physicists Colloquium, organized by The Indian Physical Society, at Calcutta, during the period 22/08/96 to 23/08/96, and and gave a lecture on *Beam optics of the Dirac particle*.

Attended the International Conference on Dynamical Systems, at the Indian Institute of Science, Bangalore, during the period 10/01/97 to 11/01/97, and presented a poster on *Transport of Dirac-particle beams through magnetic quadrupoles*.

Attended the School on Physics of Beams, held at Centre for Advanced Technology (CAT), Indore, during the period 13/01/97 to 25/01/97, and gave a lecture on *Beam optics of the Dirac particle*.

Attended the Winter College on Quantum Optics: Novel Radiation Sources, held at ICTP, Trieste, during the period 03/03/97 to 21/03/97; gave a lecture on *Quantum mechanical approach to beam physics*.

Visited Dipartimento di Fisica dell'Università di Padova, INFN, Sezione di Padova, Italy, during the period 25/03/97 to 27/03/97.

Kodiyalam, Vijay:

Participated in the Conference on Topology and Geometry at I.I.Sc., Bangalore during the period 18th to 23rd December 1996.

Gave a course of 20 lectures on *Groups and Symmetry* at the MTTS programme conducted at I.I.T., Chennai, during the period 22/5/97 to 17/6/97.

Krishna, M.:

Gave a course of 7 lectures on *Real Analysis* at the (NBHM supported) MTTS programme held at Fergusson College, Pune, during the period 20/5/96 to 1/6/96.

Lectured on *Inverse spectral theory in one dimension*, at the Indian Statistical Institute, Bangalore, on 13/10/96.

Attended the Symposium on Harmonic Analysis at the Ramanujan Institute for Advanced Study in Mathematics, Madras University, during the period 13/3/97 to 15/3/97; and gave a lecture on *Inverse spectral theory.*

Visited University of Bochum, Germany during 31 March - 17 April 1997.

Lectured on *Anderson Model with decaying randomness* at Institute fur Reine und Angewandte Mathematik, Aachen, Germany, on 12/4/97.

Gave a course of 11 lectures on *Complex Analysis*, at the (NBHM supported) MTTS programme at the Indian Institute of Technology Chennai, during the period 22/5/97 to 16/6/97.

Lodaya, Kamal:

Participated in the Workshop on Applied Formal Methods, 14-17 Dec 1996, Hyderabad.

Participated in Sixteenth Foundations of Software Technology and Theoretical Computer Science (FST&TCS) 1996, 18-20 Dec 1996, Hyderabad.

Participated in Seventh National Seminar on Theoretical Computer Science, held at the Madras Christian College, during 11-14 June 97, Chennai. (Was also a Member of the Organizing Committee.)

Madhusudan, P.:

Attended the Sixteenth Foundations of Software Technology and Theoretical Computer Science (FST&TCS) Conference, held at the University of Hyderabad during 18–20 December 1996.

Attended 'Indo-French School on Abstract Interpretations' in Bangalore, April 1997.

Attended the National Seminar on Theoretical Computer Science at MCC, Madras in June, 1997.

Mahajan, Meena:

Visited the Department of Computer Science and Automation, Indian Institute of Science, Bangalore, from 8 – 19 April, 1996, and again from July 14 to August 1 1997.

Attended the Sixth National Seminar on Theoretical Computer Science 1996, held at the Banasthali Vidyapeeth, Rajasthan, India from 5–8 Aug 1996, and gave a tutorial on *Applications of Universal Hashing in Complexity Theory.*

Attended the Sixteenth Foundations of Software Technology and Theoretical Computer Science (FST&TCS) Conference, held at the University of Hyderabad during 18–20 December 1996.

Attended the Seventh National Seminar on Theoretical Computer Science, held at the Madras Christian College during June 11–14, 1997. Was a member of the Organising Committee.

Majumdar, Parthasarathi:

Visited the TNP Division, Saha Institute of Nuclear Physics, Calcutta, during July 1-30, 1996, and again during July 21-25, 1997, and lectured on *Fermions in black hole spacetimes* on July 17, 1996, and on *Fermion emission from black holes and brane decay* on July 21, 1997.

Visited the Relativity and Cosmology Centre, Physics Department, Jadavpur University, Calcutta, during February 1-28, 1997, as well as during May 5-9, 1997 and July 28-31, 1997, and gave the following seminars on the indicated days:

Black hole radiance and supersymmetry, on February 20th, 1997.
Aspects of quantum gravity, on May 3rd, 1997.
Is a black hole really a black body ?, on July 29th, 1997.

Majumdar, Pushan:

Attended the XIth SERC school held at Punjab University, Chandigarh during the period April 1 - 27 , 1996.

Attended a Workshop On Frontiers in Field Theory, Quantum Gravity And String Theory held during December 12 - 21, 1996 at Puri.

Attended the XIIth DAE Symposium on High Energy Physics at the Department of Physics, Gauhati University during 26-12-1996 and 1-1-97, and presented a contributed paper titled *Solution of the Non Abelian Gauss Law And Duality Transformation.*

Attended the XIIth DST-SERC School on Theoretical High Energy Physics held at CTS-IISc.-Bangalore during 16-2-97 and 9-3-97.

Attended the 1997 BCSPIN Kathmandu Summer School in Physics on "Current Trends in High Energy Physics and Cosmology" during 19-5-97 and 3-6-97, and gave a seminar titled *Distribution Functions For Gluons Obeying Twisted Boundary Conditions.*

Mishra, A.K.:

Visited Central Electrochemical Research Institute, Karaikudi from Oct. 29 to Nov. 5. 1996. Participated in a Brain-storming session on Trends in Researches in Electrochemical Surface Science, and gave a talk on *Electronic Structure of Chemisorbates at Electrochemical Interface.*

Participated in Discussion Meeting on Theoretical Chemistry at Kottayam (Dec. 5-8, 1997) and gave a talk on *Chemisorption at Electrode-Electrolyte Interface.*

Gave a talk on *Electrochemical Interface* at RRL, Bhopal on 31.12.97.

Participated in IUPAC International Conference on Chemical and Biological Thermodynamics at Guru Nanak Dev University, Amritsar (January 5-8, 1997) and presented a contributed paper on *Adsorbate Layers at Electrochemical Interface: Electronic Structure.*

Mohalik, Swarup Kumar:

Gave a talk in the Dept. of Computer Science, University of Hildesheim, Germany, on *Decomposition of Asynchronous Automata* on 25th July, 1996.

Participated in the Summer School on Mathematical Models for Program Development at Marktoberdorf, Germany, during July 30 – August 11, 1996.

Visited the United Nations University / International Institute for Software technology, Macau for three months in Sept.- Nov., 1996.

Murthy, M.V.N.:

Visited the Department of Physics and Astronomy, McMaster University, Hamilton, Ontario, Canada for the period July 1996 - June 1997.

Mohan, Radha:

Attended the NBHM School on Complete Intersections at IISc., Bangalore during the period 20/5/1996 to 8/7/1996, and gave a talk on *Core of a Module over a two-dimensional regular local ring.*

Gave a talk on *Multiplicity in graded rings* at ISI, Delhi on 17/12/1996.

Nag, S.:

Visited the University of Lublin and the Banach Center in Warsaw from August 15th to 22nd 1996.

Visited the University of Southern California, Los Angeles, USA, from August 28th 1996, to August 31st 1997. Taught courses on *Differentiable Manifolds, Differential Geometry of Curves and Surfaces*, and *Vector calculus*. Also ran a graduate student seminar-course on *Riemann surfaces and Algebraic curves* in the summer session 1997.

Was "Main Lecturer" at the Finnish-Polish-Ukrainian School and Conference on Complex Analysis, Lublin, August 15 to 21, 1996, where he delivered a series of talks.

Lectured at the Geometry Seminar at USC Los Angeles, October 1996.

Gave a colloquium at the Florida State University, Tallahassee, on *Riemann surfaces and strings*, in November 1996.

Gave a colloquium at the Louisiana State University, Baton Rouge, on *Moduli of Riemann surfaces and the Polyakov string*, in March 1997.

Nagaraj, D.S.:

Gave a course of 18 lectures and problem sesions on *Algebra* at the MTTS programme conducted by NBHM at IIT, Chennai, during the period 22/5/97 to 17/6/97.

Attended the conference on *Algebraic and Differential Geometry* held at T.I.F.R., Mumbai, during the period 17/7/97 to 23/7/97.

Nagaraj, S.V.:

Participated in Sixteenth Foundations of Software Technology and Theoretical Computer Science (FST&TCS) 96, during December 18th to 20th, 1996, at the University of Hyderabad.

Participated in the National Seminar on Theoretical Computer Science held at Madras Christian College, Chennai during June 11th to 14th, 1997.

Paranjape, K.H.:

Lectured on *Seiberg-Witten Invariants*, at the Topology and Geometry conference, JNCASR-ISI, 1996, Bangalore, India.

Lectured on various topics in Instructional Workshop on Algebraic Geometry, April 1997, S. N. Bose National Centre for Basic Sciences, Calcutta, India.

Lectured on *Witten's analytic proof of Morse inequalities* at ISI, Bangalore on June 12th 1997.

Parthasarathy, R.:

Visited the Department of Physics, Simon Fraser University, Burnaby. B.C., Canada, during October - December 1996.

Visited the Departments of Mathematics and Physics at the University of Illinois, Urbana, U.S.A, for a week from 9 November 1996 to 14 November 1996, and gave seminars on *Harmonic Gauss maps and self-dual equations*, and on *QCD strings as Grassmannian sigma model*.

Rajasekaran, G.:

Attended the Golden Jubilee Symposium on Theoretical Physics, TIFR, Mumbai, September 1996, and gave a talk on *My failures in Quantum Field Theory*.

Led the Indian delegation to the 22nd General Assembly of the International Union of Pure and Applied Physics, (IUPAP) held at Uppsala, Sweden (September 1996).

Attended the Tenth Anniversary Symposium on Physics, JNU, Delhi, October 1996, and gave a lecture on *Qauntum Field Theory with antiparticles having no hair*.

Attended the XII Symposium on High Energy Physics, Gauhati University, Guwahati, during Dec.26, 1996 - Jan.1, 1997, and gave the summary talk entitled *Summary and Perspectives in High Energy Physics*.

Lectured on *Chandrasekhar and Stars* at the Student Program at IGCAR, Kalpakkam, on 21st May 1996, and also at Periyar Centre for Science and Technology, Madras.

Lectured on *High Energy Physics and String Theory* at Indian Physics Association, Kalpakkam Chapter, on 21st May, 1996.

Lectured on *High Energy Physics - Present and Future* at Centre for Advanced Technology, Indore on 22nd January 1997.

Gave a Colloquium *Is there a final theory?* at Raman Research Institute, Bangalore, on 6th February 1997.

Rajesh, M.:

Gave talks on *Statistics and Probability*, and on *Sequences and Series*, at the Children's Club, Madras in April 1996.

Attended the *First School on Non-linear Functional Analysis and its Applications* held at the International Centre for Theoretical Physics, Trieste, Italy, from April 15 to May 3rd, 1996.

Participated in the International Conference on Partial Differential Equations at TIFR, Bangalore from August 26th to 30th 1996 held in connection with the Golden Jubilee celebrations of TIFR.

Visited the Tata Institute of Fundamental Research at Bangalore in October 1996 for a period of one month to work with Prof.Vanninathan and Prof.Nandakumaran.

Gave a talk on *Fourier Series*, at the Siddhartha College at Vijayawada, Andhra Pradesh on December 21st, 1996.

Attended the *Second School on Non-linear Functional Analysis* at ICTP, Trieste, Italy during April 21st to May 5th, 1997.

Ramachandran, R.:

Participated in the Indian Academy of Science midyear meeting at Bangalore July 19-20, 1996.

Participated in SUJAYATA Golden Jubilee Theoretical Physics Symposium, Tata Institute of Fundamental Research, Bombay Sept 2 - 7, 1996.

Participated in the Workshop on Field Theory, Quantum Gravity and String Theory, Puri in Decmber 12 - 20, 1996 and gave the inaugural address entititled *A new era in String Theories*.

Participated in the XII DAE Symposium on High Energy Physics Symposium at Gauhati University, Dec 26, 1996 - Jan 1, 1997. (Was also a member of the Organising Committee).

Participated in the VII Session of the Joint Council of Indo Russian Integrated Long Term Program (ILTP) of Co-operation in Science and Technology Delhi January 8 - 9, 1997. (Is also the Area Coordinator for Mathematics and Mathematical Sciences.)

Visited the Inter University Centre for Astronomy and Astrophysics, Pune during January 16 - April 15, 1997. Gave a short course of 9 lectures on *Standard Model* to Scientists at IUCAA/NCRA during March 1997.

Delivered a public lecture on *Elementary Particle Zoo* at Chandra sekhar Auditorium IUCAA Pune, to about 300 High School Students from Pune as a part of the Popular Science Program of IUCAA.

Participated in the Workshop on DAE Vision of Information Exchange, BARC Mumbai April 10-11, 1997.

Gave a talk on *Developments in String theory* at Physics Department, Pune on April 11, 1997.

Ramakrishna, S.:

Attended the Eleventh International Conference on Photchemical Conversion and Storage of Solar Energy (IPS-11), held at Bangalore between 28th July to 2nd August of 1996.

Attended the Discussion Meeting on Theoretical Chemistry, organized by the School of Chemical Sciences, Mahatma Gandhi University, Kottayam Kerala, during the period 5th to 8th of December 1996 and gave a talk on *Carrier Relaxation in the presence of a depletion layer at semiconductor electrodes* on 6/12/96.

Raman, Venkatesh:

Visited the Computer Science Department of University of Rhode Island, Kingston, USA from 1st to 9th June 1996; gave a talk on June 4, 1996 titled *Fixed Parameter Tractability of Graph Problems*.

Gave a talk on *Fixed Parameter Complexity* at the University of Pennsylvania, on June 24, 1996.

Participated in the Sixth National Seminar on Theoretical Computer Science at Banasthali, Rajasthan August 5-8, 1996.

Participated in the 16th FST&TCS conference in Hyderabad from December 18-20, 1996.

Presented special lectures on January 11, 1997 titled *Selection Problems*, and on March 8, 1997 titled *Minimum Spanning Tree Algorithms* in the Saturday lecture series organized by the Manonmaniam Sundaranar University at St. Xavier's College, Palayankottai.

Participated and gave an invited talk on *Parameterized Complexity* in the Seventh National Seminar on Theoretical Computer Science at MCC Chennai from June 11-14, 1997.

Ramanujam, R.:

Visited the Mathematics and Information Science Department of Rutgers University (Camden), U.S.A. during April 5 to April 26, 1996.

Gave lectures on *Logics over knowledge transition systems*, at the Università di Roma 'La Sapienza', Rome, on April 3, 1996, and at the Knowledge Seminar, Graduate Center, City University of New York, on April 19, 1996.

Attended the IEEE Conference on Logic in Computer Science, Rutgers University, U.S.A, July 26 to 30, 1996; presented a paper titled, *Locally linear time temporal logic*.

Gave lectures on different aspects of *partial order based temporal logics*, and the notion of *trace consistency*:

- at the Software Security and Verification Group, Naval Research Laboratory, Washington D.C, on August 2, 1996,
- at the Computer Science Department, State University of New York at Stony Brook, on August 7, 1996,
- at A T & T, Bell Labs, New Jersey, on August 9, 1996,
- at the Computer Science Department, Concordia University, Montreal, on August 13, 1996,
- at the Computer Science and Engineering Department, IIT-Kharagpur, on January 17, 1997, and
- at the Computer Science Department, Motilal Nehru Engineering College, Allahabad, May 5, 1997.

Attended the Sixteenth international conference on Foundations of Software Technology and Theoretical Computer Science, Hyderabad, December 18 to 20, 1996; presented a paper titled, *Trace consistency and inevitability*. Co-organised the Special Session in honour of Professor Rohit Parikh at FST & TCS, Hyderabad; gave a talk titled, *View-based explicit knowledge*.

Gave a course of 7 lectures on *Logics of Knowledge* at the Winter School on logic in computer science at Indian Statistical Institute, Calcutta, from January 6 to 11, 1997.

Attended the Seminar on Cognition, Jadavpur University, Calcutta, January 13 to 15, 1997; gave a set of three lectures on *The logical omniscience problem*.

Gave introductory lectures on *Knowledge in distributed systems*, at the IEEE Chapter, Kharagpur, on January 16, 1997, and at the CSI Chapter, Allahabad, on May 3, 1997.

Attended "Indo-French School on Abstract Interpretations" in Bangalore, April 1997.

Gave introductory lectures on *Agreeement problems in distributed systems*, at JK Institute, Allahabad University on May 2, 1997, and at the MTTS Programme, IIT-Chennai, on June

6, 1997.

Attended the National Seminar in Theoretical Computer Science, Madras Christian College, Tambaram, June 11 to 14, 1997; gave a 4-lecture tutorial titled, *Agreement among rational agents*.

Gave introductory lectures on *Quantum computation* at Mehta Research Institute, Allahabad, on May 6, 1997, and at the Computer Science and Engineering Department, IIT-Kanpur on May 9, 1997.

Rao, Madan:

Visited ICTP, Trieste, Italy from the 28th June - 31st August 1996. Participated in the Workshop on Membranes, Proteins and their Interaction, during June-July 1996 and in the workshop on Dynamics of Non-Equilibrium Systems in August 1996.
Delivered tutorial Talks on *Dynamics of Phase Ordering* as well as a talk on *Dynamics and Morphology of Martensites* in the workshop on Dynamics of Non-Equilibrium Systems.

Visited the Complex Fluids Group at the FOM, Amsterdam, Netherlands, during the first week of September 1996; delivered a talk on *Statistical Mechanics of Martensites*.

Participated in the DAE-Solid State Physics Symposium, held at BARC, Bombay during December 1996; gave a talk on *Dynamics of Fluid Membranes*.

Ray, Purusattam :

Visited Boston University, Boston, U.S.A., during the period May 1 to June 30, 1996: gave a talk on *Fully frustrated XY model in 3 dimensions* on 13.5.96.

Sabu, N.:

Attended the first school on non-linear functional analysis and applications to differential equations at ICTP Italy during the period 15th April to 3rd May 1996.

Attended the second school on non-linear functional analysis and applications to differential equations at ICTP Italy during the period 20th April to 9th May 1997.

Visited Prof Nandakumar at TIFR Bangalore during the period 18th August to 4th September 1996.

Sarkar, Tapobrata :

Attended the Summer School on High Energy Physics and Cosmology, I.C.T.P, Trieste, Italy (10th to 27th June, 1996).

Visited the International Centre for Theoretical Physics, (ICTP) Trieste, Italy for the period 28 June, 1996 to 28 July, 1996.

Attended the Workshop on Planck Scale Physics, Puri, India (12th to 21st December, 1996).

Attended the Trieste Conference on String Dualities, I.C.T.P, Trieste, Italy (1st to 4th April, 1997).

Attended the Spring School on String Theory, Gauge Theory and Quantum Gravity, I.C.T.P, Trieste, Italy (7th to 12th April, 1997).

Sathiapalan, Balachandran:

Participated in the Workshop on Frontiers in Field Theory, Quantum Gravity and String Theory, held at Puri, December 12-21, 1996; gave a talk on *Loop Variables and Gauge Invariant Interactions in String Theory*

Sengupta, Gautam :

Visited the Center for Theoretical Studies, Indian Inst. of Science, Bangalore during August 1996; gave a seminar entitled *S-duality and Exact Superstring Backgrounds*.

Attended International Workshop on Strings. Fields and Gravity at Puri, India during December 1996.

Visited Saha Inst. of Nuclear Physics, Calcutta during December 1996; gave a seminar entitled *S-duality and Exact Superstring Backgrounds*.

Visited Theory Divison, CERN, Geneva, Switzerland during April 1997.

Attended Trieste Duality Conference-II, at ICTP, Italy during April 1997.

Attended Spring School on String Theory and Quantum Gravity at ICTP, Trieste, Italy during April 1997.

Seth, Anil:

Visited DIMACS (Center for Discrete Mathematics & Theoretical Computer Science), Rutgers university, from April 17, 1996 to July 30 1996 as part of its special year on Logic and Algorithms.

Attended the conference on Feasible arithmetics and length of proofs, April 21-23, 1996 at DIMACS.

Gave a talk on *Implicit definability vs. weak implicit definabilty in finite model theory* on June 7, 1996 at DIMACS.

Attended the Second annual meeting on DNA based computers, June 10-12, 1996 at Princeton University.

Attended the Workshop on computational complexity and programming languages, July 25-26, 1996 at DIMACS.

Gave a talk on *Implicit definability vs. weak implicit definabilty in finite model theory* on July 11, 1996 at City University of New York.

Attended the Eleventh annual symposium on Logic in Computer Science, July 27-30, 1996, Rutgers, New Jersey.

Attended the Workshop on formal methods, December 14-17, 1996, Hyderabad.

Attended the FST & TCS conference, December 18-20, 1996, Hyderabad.

Shankar, R.:

Participated in the Conference on "Frontiers in Materials Modelling and Design", 20-23 August, 1996, IGCAR, Kalpakkam; gave a talk on *Crystalline ground states of quantum Hall skyrmions.*

Participated in the IX Trieste workshop on "Open Problems in Strongly Correlated Systems", 14-25 July 1997, ICTP, Trieste, Italy.

Participated in the International workshop on 'Novel Physics in Low-Dimensional Electron Systems', 28 July- 8 August, 1997, Dresden, Germany; gave a talk on *Shape and Phase transitions in quantum Hall Skyrmions.*

Sharatchandra, H. S.:

Attended the 'Puri Workshop on Frontiers in field theory, quantum gravity and string theory', Puri, December 12-21 1996, and gave a talk entitled *General solution of the non-Abelian Gauss law and non-Abelian duality transformation.*

Shubashree, D.:

Visited the International Centre for Theoretical Physics at Trieste, Italy, during 30/9/96 - 29/10/96.

Lectured on *Quantum Antiferromagnets: From the Triangular to the Kagome Lattice* at the School of Physics of the University of Bologna, Italy on 23/10/96 and at the Solid Staet Physics Lab at the University of Paris (P-Sud), France on 28/10/96.

Lectured on *Field Theory of Quantum Antiferromagnets: From the Triangular to the Kagome Lattice* at the Mehta Research Institute, Allahabad on 12/3/97, and at the Indian Institute of Science, Bangalore on 27/3/97, as well as at the Theoretical Physics Department of the University of Madras on 3/4/97.

Simon, R.:

Attended a Workshop on the Foundations of Quantum Theory (A Golden Jubilee event of TIFR) at the Tata Institute of Fundamental Research, Mumbai, during the period 9th - 12th September 1996; and gave a talk on *The geometry of interference in phase space.*

Visited the Centre for Theoretical Studies, Indian Institute of Science, Bangalore for one week in November 1996.

Attended the International Conference on Dynamical Systems at the Indian Institute of Science, Bangalore, during 10th - 15th January 1997, and gave a talk on *From moment invariants to generalized uncertainty principle.*

Visited the Raman Research Institute, Bangalore for a week in April 1997; and gave a lecture on *The role of Pancharatnam phase in qunatisation of classical orbits: Application to asymptotic form of special functions* on April 16th.

Sinha, Rahul:

Visited Delhi University for a month in May 96, for research collaboration with Prof. S. Rai Choudhury.

Attended the Conference cum work shop on High Energy Physics and Computational Physics, held at Delhi University during September 30th - 11th October 1996, and gave a lecture on *CP violation: The Physics of Beauty.*

Sinha, Sudeshna:

Attended the "Workshop on Complex Systems" in Bangalore from 26 - 29 June 1996, and gave a talk on *Coupled Map Lattices.*

Attended the "Workshop on Recent Developments in Chaotic Dynamics", Tiruchirapalli, 9 - 13 December 1996, and gave two talks, one on *Adaptive Dynamics on Chaotic Lattices* and the other on *Globally Coupled Maps.*

Attended the "International Conference on Dynamical Systems", Bangalore from 10 - 15 January 1997.

Visited the Applied Chaos Lab, School of Physics, Georgia Institute of Technology, Atlanta, Georgia, USA, during the period 21 March - 8 April 1997.

Srinivas, K. :

Visited the School of Mathematics, TIFR, Mumbai during the period 27th January to 10th February, 1997.

Attended the Symposium on Harmonic Analysis at the Ramanujan Institute for Advanced Study in Mathematics, Madras University, during the period 13/3/97 to 15/3/97.

Gave a course of 23 lectures on *Number Theory* at the MTTS programme conducted by the NBHM at IIT, Chennai during the period 22/5/97 to 17/6/97.

Srinivasa Rao, K.:

Delivered the "Key-note address" at the 'Ramanujan Remembrance Day', Ramanujan Museum, Mathematical education Center, Royapuram, on 26/4/96.

Visited the Arnold Sommerfeld Institute for Mathematical Physics, Technical University of Clausthal, Germany, during August 1996. Gave talks on *Recent developments in and from the quantum theory of angular momentum :*
1. Sets of hypergeometric functions, summation theorems and transformations,
2. Group thory of ${}_3F_2(1)$ *terminating series,*
at the institute on 22/8/96 and 23/8/96, respectively.

Visited the Department of applied Mathematics and Computer Science, University of Gent, Belgium, during September 1996.

Visited the Institute for Theoretical Nuclear Physics, University of Bonn, Bonn, Germany, during October 1996, and gave a talk on *Recent developments in and from quantum theory of angular momentum.*

Gave a talk on *Generalized hypergeometric series and the quantum theory of angular momentum*, at the Department of Mathematics, University of Amsterdam, The Netherlands, on 11/10/96.

Gave a talk on *Recent developments in and from quantum theory of angular momentum*, at the Department of Physics, University of Göttingen, Göttingen, Germany, on 17/10/96.

Gave a talk on *Life and work of Srinivasa Ramanujan* at the Physikalisches Institut der

Universität Bonn, Bonn, Germany, on 28/10/96.

Gave two lectures on *Life and work of Srinivasa Ramanujan*, at the Birla Institute of Technology and Science, Pilani, on 1/11/96.

Gave a talk on *Frontiers in 21st century*, in 'Vistas of 21st Century of Physics,' at the Department of Physics, St. Joseph's College, Tiruchirapalli, on 28,29/11/96.

Spoke on *A glimpse into Ramanujan's Mathematics*, in the One Day Symposium on Mathematical Methods and Applications, conducted by the Department of Mathematics, I.I.T., Madras, on 22/12/96.

Srinivasa Rao, S.:

Participated in the National Seminar on Theoretical Computer Science held at Banasthali Vidyapith, Rajasthan during August 5 to 8, 1996.

Participated in the FST & TCS conference held at University of Hyderabad during Dec 18 to 20, 1996.

Participated in the National Seminar on Theoretical Computer Science held at Madras Christian College during June 11 to 14, 1997.

Subramoniam, G.:

Participated in a Training programme under the Integration of Computing Facility for Scientific Research (ICOSER) project of TIFAC, DST from January 27 to February 7, 1997 at SERC, Indian Institute of Science, Bangalore.

Gave a talk on *Accessing Research Information from Internet* in December 1996, at MALIBNET, INSDOC, CSIR, Chennai.

Gave a talk on *Internet Services for Educational Institutions* in January 1997 at Barathidashan University, Trichirapalli.

Gave a talk on *Internet for information exchange* in February 1997, at the Dept. of Physics, Presidency College, Chennai.

Gave a talk on *Information Access Through Internet* in March 1997 at Annamalai University, Annamali nagar, Chidambaram.

Sunder, V. S.:

Gave a course of 12 lectures on *Probability and Measure* at the MTTS programme conducted

by the NBHM at Fergusson College, Pune, during the period 20/5/96 to 15/6/96.

Attended the Aegean Conference on Operator Algebras, held at Samos, Greece, during the period 17th to 27th of August, 1996; and gave a talk on *Discrete hypergroups and their actions on sets*.

Visited the Mathematics Institutes of the Universities of Aarhus, Odense and Copenhagen in Denmark, during the period 1st to 21st of September, 1996. Gave a talk on *Hypergroups and Subfactors* at the Math Institut, Aarhus, on 6/9/96; and on *Non-unimodular discrete hypergroups* at the Math Institut, Odense, on 12/9/96; and on *Vertex models* at the Math Institut, Copenhagen on 20/9/96.

Attended the Seminar on Recent Developments in Mathematics and its Applications, at Seethalakshmi Ramaswami College, Tiruchirapalli, on 23/1/97; gave a talk on *Knot Theory* at the Seminar.

Visited the School of Mathematics at the University of New South Wales, Sydney, Australia, during the period 1st February to 1st March, 1997; gave a talk on *Do subfactors remember subgroups ?* on 21/2/97.

Gave a talk on *Discrete Hypergroups*, at the University of Newcastle, Newcastle, Australia, on 24/2/97.

Attended the Symposium on Harmonic Analysis at the Ramanujan Institute for Advanced Study in Mathematics, Madras University, during the period 13/3/97 to 15/3/97, and gave a talk on *Fusion algebras and Cartan subalgebras* on 14/3/97.

Visited the Indian Statistical Institute, Bangalore from 13th to 26th April, 1997; and gave a talk on *The subgroup-subfactor*.

Attended the Mid-Year Meeting of the Indian Academy of Sciences at Bangalore during June 18th - 19th, 1997.

Surya Ramana, D.:

Attended a two month long course on *elliptic curves* given by Prof. J.Osterele at MRI, Allahabad from Dec. 1996 to Feb. 1997.

Vathsan, Radhika:

Attended the SUJAYATA Golden Jubilee Symposium in Theoretical Physics at TIFR, Bombay, during 2-7 September 1996.

Vinodchandran, N. V.:

Gave a talk on *The Complexity of Exactly Learning Algebraic Concepts* in the Dept. of Mathematics and Computer Science, University of New England, Australia, on 21/10/96.

Attended the Seventh International Workshop on Algorithmic Learning Theory held at Sydney, Australia, during 23 to 25th of October, 1996; presented the contributed paper *The Complexity of Exactly Learning Algebraic Concepts* on 23/10/96.

Gave a talk entitled *Solvable Group problems are Low for PP* in the Mathematics and Computing section of the School of MPCE, Maquarie University, Australia, on 30/10/96.

Gave a talk emtitled *The Complexity of Computational Problems over Finite Groups* in the Department of Computer Science, University of New South Wales, Australia, on 1/11/96.

Attended the 16th International conference on Foundations of Software Technology and Theoretical Computer Science, during 18 to 20th of December, 1996.

Attended the 7th National Seminar on Theoretical Computer Sciences held at Madras Christian College, Chennai during 11 to 14th of June, 1997.

2.8 Other Professional Activities

Arvind, V. :

Member, Programme Committees for the 1996 Foundations of Software Technology and Theoretical Computer Science Conference, and the 1997 National Seminar in Theoretical Computer Science.

Balasubramanian, R.:

Member, NBHM
Member, Board of Research Studies, Madras Univ.
Member, Board of Studies, Mathematics PG, Madras Univ.
Member, Editorial Board of the Newsletter of Allahabad Academy.
Member, Editorial Board of *National Academy Science letters* of National Academy of Sciences, India.
Member, Sectional committee of National Academy of Sciences.
Member, Management Advisory Committee of D.S.T.
Member, Editorial Board, Indian J. of Pure and Appl. Math.

Baskaran, G.:

Member, Sectional Committee for Physics, Indian National Science Academy.
Member, Editorial Board, Indian Journal of Pure and Applied Physics.
Member, Working Committee of Current Science Association.
Member, National Committee of the International Union of Pure and Applied Physics.
Member, Scientific Council of the International Center for Condensed Matter Physics, Brasilia, Brazil.

Basu, Rahul:

Represented the institute at the DAE Vision on Information Exchange '97 meeting held on 10, 11 April 1997.
Presented a poster giving details of the IMSc computer network and expertise and also gave a talk on related matters in the same meeting.

Kesavan, S.:

Member, NBHM Sub-Committee for Nurture Programmes.
Convener, Faculty of the Nurture Programme 1995-96.
Member, Board of Studies, Cochin University of Science and technology, Cochin.
Member, Advisory Board, Indian Journal of Pure and Applied Mathematics, INSA.

Was co-opted as a member of the Committee for the Library Assistance Programme of the NBHM and inspected the libraries of the ISI,Bangalore, Karnatak University, Dharwad, Kuvempu University, Shimoga and Mysore University, Mysore, in August 1996.

Mishra, A.K.:

Associated with various activities of SLET, Bharathidasan University.

Nag, S.:

Member, Advisory Board, Indian Journal of Pure and Applied Mathematics.

Paranjape, K.H.:

Associate Editor for The Proceedings of the Indian Academy of Sciences, (Mathematical Sciences).
Member of the Editorial Board for the Journal of the Ramanujan Mathematics Society.
Member of the Editorial Board for 'Resonance', A Journal of Science Education.

Rajasekaran, G.:

Chairman, National Committee of the International Union of Pure and Applied Physics.
Member, National Committee of the International Council of Scientific Unions.
President, Indian Physics Association (Madras Chapter).
Convener, Madras Chapter of the Indian National Science Academy.
Member, Governing Council of the Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad.
Member, Special Committee of the School of Physical Sciences, JNU, New Delhi.
Member, Editorial Board of Indian Journal of Pure and Applied Mathematics.
Edited Special Section on "High Energy Physics in the 21st century", *Current Science* **71** (1996) 109-127.
Organized the INSA-IMSc Symposium on Neurosciences in honour of Dr. B. Ramamurthy on the occasion of his 70th birthday at IMSc., Madras on 26 April '97.
Edited "Physics in India - Status Report (1996)" published by Indian National Science Academy, New Delhi.

Ramachandran, R.:

Member, Sectional Committee for Physics, Indian Academy of Science, Bangalore.
Member, Board of Studies, Indira Gandhi National Open University, New Delhi.
Member, School of Physics Board, University of Hyderabad.
Member, Planning Board, Manonmaniam Sundaranar University, Thirunelveli.
Member, Board of Research, University of Madras, Madras.
Member, Strategic Planning Committee at IIT Madras.

Member, Working Committee of Current Science Association.
Area Co-ordinator for Mathematics and Mathematical Sciences of the Indo Russian Integrated Long Term Program (ILTP) of Co-operation in Science and Technology.

Ramanujam, R.:

Member of the Programme Committee for the conference on Algebraic Methodology and Software Technology, Muenchen, Germany, July 1-5, 1997.

Raman, Venkatesh:

Member of the Program Committee for the 17th FST&TCS conference to be held in Kharagpur in December 1997.

Sarkar, Tapobrata:

Was teaching assistant for the courses *Quantum Field Theory* and *Particle Physics* during January-May 1997.

Organised a summer school in Physics (for school students upto standard 12) on behalf of Childrens' Club Society, Chennai, during 18th May to 6th June, 1997.

Srinivasa Rao, K.:

Organised the release of the Indian Edition of the book : *Ramanujan : Letters and Commentary*, Edited by Bruce C. Berndt and Robert A. Rankin, and published by the American Math. Soc. and the London Math. Soc. (1995). The Indian Edition is published by the Affiliated East West Pub. (P) Ltd. with a Preface to and Additions to the Indian Edition by K. Srinivasa Rao and an Errata.

Sunder, V.S.:

Member, Editorial Board of the Journal of the Ramanujan Mathematics Society.
Member, Sectional Committee for Mathematics, Indian Academy of Sciences, Bangalore.

2.9 Honours and Awards

Kapil H. Paranjape was elected a Fellow of the Indian Academy of Sciences, Bangalore.

V.S. Sunder was awarded the Shanti Swarup Bhatnagar Award for Mathematical Sciences for the year 1996; the citation accompanying the award read as follows:

The Shanti Swarup Bhatnagar Prize for the year 1996 in Mathematical Sciences has been awarded to Dr. Viakalathur Shankar Sunder, Institute of Mathematical Sciences, Chennai, for his discovery of integral hypergroups which describe the fusion rules governing the irreducible bimodules coming from a subfactor in the theory of von Neumann algebras. This has led to the important conclusion that certain graphs cannot arise as principal graphs of subfactors, thereby settling a well-known conjecture of Ocneanu.

Chapter 3

Computer Facilities

In the current report period, there was further significant strengthening of the Institute computer system and internet services.

In terms of hardware, a SGI Power Challenge-L, with two R8000 CPUs (90 MHz) and 128 Mb of RAM was added to the system. Two SUN machines were also added; the first was a SUN UltraSparc-1 (140MHz) and the second a 2-CPU Sun UltraSparc-2 (166 MHz). A purchase order has also been placed for a twin-tower SGI Origin 200 machine with a CrayLink Interconnect. (with a total of four R10000 CPUS at 175MHz and 256 Mb of RAM). THe Power Challenge L is also to be upgraded with the addition of two more CPUS and 128 Mb RAM.

With this hardware and the commissioning of a new 30 KVA UPS (backed up by a generator) the IMSC computer system has provision for uninterrupted high-quality computing work.

Internet services have been functioning regularly through the VSAT network of ERNET. The Institute has now become a regular ERNET node with the signing of a Memorandum of Understanding with ERNET. As an ERNET node, construction is underway of a 64 KBps link to the internet through VSNL, Chennai which is to be eventually upgraded to 2Mbps. The 64 Kbps link is expected to be functional shortly. With this addition, the Institute will also provide Internet connectivity to various other institutions in the area on behalf of ERNET.

A significant new service on the system has been the setting up of a mirror site of the Los Alamos physics and mathematics e-print archives; http://xxx.imsc.ernet.in. This project is due to be thrown open for regular service shortly. This will provide users in India an alternate ready access to the vast majority of current literature published in several areas of mathematics and physics. IMSc also hosts and maintains the official web-site of the Indian Association for Research in Computer Science (IARCS).

The Institute of Mathematical Sciences also has a popular web-site at http://www.imsc.ernet.in that is frequently accessed with several pages of information about the Institute and its research, on science and popular science, web-sites in India, etc.

The Institute now has significant know-how among its faculty and students in several

areas of computing and system management, networking, Internet services, web-server management and web-page design, etc. A one-day workshop on Internet services was conducted for more than 50 scientists and college faculty on 16th November, 1996.

The system is managed by one full-time system administrator, Dr. G. Subramoniam.

Chapter 4

The Library

With its collection of basic and advanced level text books and research monographs and its fairly comprehensive list of subscriptions to research journals covering Mathematics, Physics and Theoretical Computer Science, the Institute Library continues to be the hub of the research activity in the Institute. Apart from serving the research needs of its members, the library also informally plays the role of a regional library, catering to the needs of scientists working in institutions in and around Chennai. It is also a member of MALIBNET - the Madras Library Network - and thus provides the institute members access to the resources of the libraries of neighbouring institutions, while, at the same time, rendering valuable service to members of those institutions.The number of users of the library from outside the institute is steadily increasing.

The library has about 15,000 books in Mathematics, Physics and Theoretical Computer Science and currently holds about 20,000 bound volumes of research journals. During the period ending March 31, 1997, 1311 books and bound periodicals were added to its collection. The library subscribes to about 260 journals of international repute, most of which arrive by air-mail. It also maintains a pre-print library and about 2140 pre-prints were received from all over the world during the year under review.

The library provides a variety of services to members of this institute and to users from outside. Its computer system has the LIBSYS software which is a fully integrated multiuser package with powerful search capabilities, available on-line. This has facilitated quick and efficient library operations. Plans are under way to upgrade this system. The library continues to get books and photocopies of research articles from other research libraries in the country via inter-library loans. Likewise, it provides the same service to other libraries by promptly responding to outside requests. The library also looks after the photocopying facility of the institute. During conferences and other related meetings, the delegates have free access to the library for reference work as well as for photocopying. The library is kept open round the clock during such periods.

The library gratefully acknowledges the donation of valuable books and journals received during the current year from the persons/organizations listed below.

1. Prof. V. Arvind
2. ICTP, Trieste, Italy
3. Dr. V. Lakshminarayanan
4. NBHM, Mumbai, India
5. DOOR Program
6. Mr.Swarup Kumar Mohalik
7. Prof. T. Oda, Tohoku Univ.
8. Prof. B. Ravikumar, Univ. of Rhode Island
9. MRI, Allahabad
10. SCES'95 (SS Physics Group)
11. Dr. K. Georgatos, Univ. di Roma
12. Prof. Charles Swartz, New Mexico Univ.
13. Mr. K.R. Nagarajan & Mr. Soundararajan
14. Prof. B. Gruber, Southern Illinois Univ.
15. Prof. Subhashis Nag
16. Prof. G. Baskaran
17. Mr. Sarasij Ray
18. Prof. V.S. Sunder
19. Springer-Verlag (Elnet, Chennai).
20. Prof. Rani Siromoney, MCC.
21. Mrs. R. Vasudevan
22. Dr. V. Subramanian
23. Prof. S. Kesavan
24. Prof. T.M. Koornwinder
25. Mr. Mohan Raman, Pallavaram.
26. Prof. R. Sridhar
27. Dr. Kamal Lodaya
28. Affiliated East-West, Madras

Special mention must be made of the contribution by Professor Rani Siromoney of Madras Christian College, Tambaram. She has donated her personal collection of journals, technical reports and seminal papers, built up over the last 30 years.

In addition to the above, a consignment of 473 books (worth about Rs. 3 lakhs) published by Springer - Verlag were received by the library from The Scientific Publishing Services (P) Ltd., Elnet, Taramani, Chennai as a token of appreciation of the lectures delivered there by Professors R. Jagannathan, R. Parthasarathy and K. Srinivasa Rao. The library records with thanks the efforts of Prof. Srinivasa Rao to obtain this donation.

Mr. K. S. Santhanagopalan (Librarian) and Mr. G. Venkatesan (Deputy Librarian) participated in a one-day seminar on "Library Networking and Resource Sharing" organized by the American Center, Chennai on Monday, March 17, 1997.

Mr. K. S. Santhanagopalan and Mr. G. Venkatesan were deputed to participate in the one-day seminar on "Recent Advances in Information Technology - READIT 97" organized by the Kalpakkam Chapter of the Madras Library Association (MALA), held at IGCAR, Kalpakkam on Wednesday, April 23, 1997.