THE INSTITUTE OF MATHEMATICAL SCIENCES

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ANNUAL REPORT

August 1999 - July 2000

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Foreword

It gives me great pleasure to present the Annual Report of the Institute for the academic year 1999-2000 for the first time in my capacity as the Director.

First of all, I place on record our deep appreciation of the distinguished service rendered to this Institute by my predecessor Prof. R. Ramachandran. Having taken over the Directorship of this Institute, a decade ago, at a crucial moment of its history, he has steered it through a period which has seen tremendous growth on all fronts - research output, faculty strength and infrastructural facilities. He had an unerring eye for quality in making faculty appointments and the appointees amply justified his faith in them by means of their outstanding research output and by the impressive list of awards and honours they won for themselves and hence for the Institute. His excellent rapport with our funding agencies has ensured that we were able to create an environment conducive for research by providing the state of art computational and communication facilities as well as a well equipped library. On the more practical plane, he worked for the general well being of the Institute members, by bringing in the CHSS Medical Scheme, by constructing staff quarters, and accommodation facilities for guests and students. The construction of the new office block, sanctioned in the Ninth Plan, is making rapid progress and we expect to occupy it in a little over a year's time. We are also happy that he will continue to serve this Institute as a Senior Professor and we will have the benefit of his experience for a few more years.

As usual, the academic year 1999-2000 has been an eventful one for this Institute with many accomplishments. The Institute has initiated an annual event, called *Foundation Day* to be celebrated on January 3 every year and on this day, an award for the best thesis coming out of this Institute would be presented. I take great pleasure in congratulating Dr. Saurya Das, the first recipient of the award. The Chief Guest of this year's function was Dr. A. Kalanidhi, Vice-Chancellor of Anna University.

Among the laurels won by our faculty members from outside, mention should be made of Prof. S. Kesavan who has received the Tamil Nadu Scientist Award for 1998. He has also received the C.L. Chandna Award (1999) for contributions to mathematical research and teaching. Prof. K.H. Paranjape was elected in 1999 as Fellow of the National Academy of Sciences, Allahabad. I take this opportunity to congratulate them and hope they and others would win such marks of appreciation and recognition from the scientific community.

The Institute has, as usual, taken the initiative to organize and to host several conferences and workshops. The series of *Workshops in High Energy Physics Phenomenology (WHEPP)*, has now stabilized in to a bi-annual event attempting to bring together active particle phenomenologists from various universities and research institutes all over India and abroad. The sixth workshop in this series - *WHEPP 6* was hosted by the IMSc this year. Another

noteworthy meeting was the mini symposium on *Motives* - a new area unifying geometry and arithmetic - held for more than a month at the Institute. It could be the beginning of a new trend - a sort of focussed visiting scientist programme. The Institute also actively took part in the organization of the annual *FST & TCS* meeting and hosted one of the satellite workshops on *Mobile Computing*. It also organized a workshop on *Recent Trends in the Quantum Hall Effect*.

Several collaborative international research projects have been awarded to members of the Institute. In particular, I would like to mention the DST-DAAD project on Theoretical Computer Science with Germany, the DST-NSF project in Mathematical Physics with USA in addition to the existing Federation Arrangement with the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

This report has been compiled through the efforts of a committee that consists of Drs. R. Sridhar, R. Anishetty, G. Date, T.R. Govindarajan, S. Kesavan, Kamal Lodaya and Mr. K.S. Santhanagopalan. I owe my gratitude to all of them.

I look back at the completed year with pride and look forward to another fruitful year of rich accomplishments.

August, 2000 **R. Balasubramanian**

Contents

Chapter 1

The Institute

PATRON Shri **C. Subramaniam**

1.1 Board

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

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

Prof. **S. K. Joshi**, Chairman, Recruitment and Assessment Centre, DRDO, Delhi and Chairman, Executive Council, The Institute of Mathematical Sciences, Chennai
(**Member**)

Prof. **A. Kalanidhi**, Vice Chancellor, Anna University, Chennai
(**Member**)

Prof. **S. S. Jha**, Director, Tata Institute of Fundamental Research, Mumbai
(**Member**)

Prof. **C. S. Seshadri**, Director, Chennai Mathematical Institute, Chennai
(**Member**)

Prof. **H. S. Mani**, Director, Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad
(**Member**)

Dr. **J. K. Bhattacharjee**, Department of Theoretical Physics, Indian Association for the Cultivation of Science, Jadavpur, Calcutta
(**Member**)

Smt. **Sudha Bhave**, I.A.S., Joint Secretary to Government of India, Department of Atomic Energy, Mumbai
(**Member**)

Sri **I. V. Manivannan**, I.A.S., Secretary to Government of Tamil Nadu, Higher Education Department, Fort St.George, Chennai
(**Member**)

Prof. **R. Ramachandran**, Director, The Institute of Mathematical Sciences, Chennai,
(**Member Secretary**) (upto June 30, 2000)

Prof. **R. Balasubramanian**, Officiating Director, The Institute of Mathematical Sciences, Chennai
(**Member Secretary**) (from July 1, 2000)

1.2 Executive Council

Prof. **S. K. Joshi**, Chairman, Recruitment & Assessment Centre, Defence Research and Development Organisation(DRDO), Lucknow Road, Timarpur, Delhi
(**Chairman**)

Prof. **C. S. Seshadri**, Director, Chennai Mathematical Institute, Chennai
(**Member**)

Prof. **H. S. Mani,** Director, Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad
(**Member**)

Dr. **J. K. Bhattacharjee,** Department of Theoretical Physics, Indian Association for the Cultivation of Science, Jadavpur, Calcutta
(**Member**)

Smt. **Sudha Bhave,** I.A.S., Joint Secretary to Government of India, Department of Atomic Energy, Mumbai
(**Member**)

Sri **I. V. Manivannan,** I.A.S., Secretary to Government of Tamil Nadu, Higher Education Department, Fort St.George, Chennai
(**Member**)

Prof. **R. Ramachandran**, Director, The Institute of Mathematical Sciences, Chennai
(**Member Secretary**) (upto June 30, 2000))

Prof. **R. Balasubramanian,** Officiating Director, The Institute of Mathematical Sciences, Chennai
(**Member Secretary**) (from July 1, 2000)

1.3 Faculty

Name	*Userid*	*Res. Phone No*
MATHEMATICS		
Balasubramanian, R.[1]	balu	245 3926
Kesavan, S.	kesh	641 2839
Kodiyalam, V.	vijay	490 2041
Krishna Maddaly,	krishna	492 8499
Nagaraj, D. S.	dsn	448 1260
Paranjape, K. H.	kapil	492 7243
Srinivas, K.[2]	srini	448 1259
Sunder, V. S.	sunder	858 3343
PHYSICS		
Anishetty, R.	ramesha	496 0586
Balakrishnan, Radha	radha	445 9653
Baskaran, G.	baskaran	492 7304
Basu, R.	rahul	245 4794, 245 3297
Chakraborty, T.	tapash	492 5271
Date, G.	shyam	245 6148
Govindarajan, T. R.	trg	492 7309
Hari Dass, N. D.	dass	442 2767
Indumathi, D.	indu	492 8138
Jagannathan, R.	jagan	
Jayaraman, T.	jayaram	492 9527
Kaul, R.	kaul	441 3264
Majumdar, P.	partha	448 0793
Menon, G. I.	menon	621 3024
Mishra, A. K.	mishra	
Murthy, M. V. N.	murthy	235 2652
Parthasarathy, R.	sarathy	
Rajasekaran, G.	graj	441 3395
Rama, S. Kalyana	krama	
Ramachandran, R.[3]	rr	442 0387
Rao, Madan[4],	madan	
Ray, P.	ray	492 8251
Sathiapalan, B.	bala	492 7832
Shankar, R.	shankar	448 1914
Sharatchandra, H. S.	sharat	441 8059
Simon, R.	simon	441 3270
Sinha, Rahul	sinha	448 2190
Sinha, Sudeshna	sudeshna	492 7243
Sridhar, R.	sridhar	441 9145
Srinivasa Rao, K.	rao	441 1347

Name	*Userid*	*Res. Phone No*
THEORETICAL COMPUTER SCIENCE		
Arvind, V.	arvind	235 2556
Lodaya, K.	kamal	445 3312
Mahajan, Meena	meena	441 3403
Raman, V.	vraman	492 9845
Ramanujam, R.	jam	492 8138
Seth, Anil[5]	seth	
SCIENTIFIC OFFICER		
Subramoniam, G.	gsmoni	237 9520
ERNET PROJECT ASSISTANT		
Suresh Rao, S.[6]	suresh	
Arun Kumar, S.[7]	arun	

email: userid@imsc.ernet.in

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[1] Officiating Director from 1.7.2000
[2] LLP from 13.7.2000 to 30.6.2001
[3] Director upto 30.6.2000
[4] on leave on lien terms with Raman Research Institute, Bangalore from 1.1.1999
[5] on academic assignment from 30.8.1999 to 31.7.2000 with Silicon Automation Systems, Bangalore
[6] resigned on 31.5.2000
[7] w.e.f. 1.6.2000

1.4 Post-Doctoral Fellows

Name	*Userid*
MATHEMATICS	
Jishnu Gupta Biswas	jishnu
Thangadurai, R.[1]	thanga
PHYSICS	
Rathin Adhikari[2]	rathin
Arun Kumar, S.[3]	arun
Gautam Dutta[4]	gdutta
Dong Shin Shin[5]	shin
Ghosh, P. K.[6]	pijush
Hiroyuki Takata[7]	takata
Mitaxi Mehta[8]	mitaxi
Nakkeeran, K.[9]	naks
Seshadri, S.[10]	sesh
Sankalpa Ghosh[11]	sankalpa
Vadim Apalkov[12]	

[1] joined on 3.9.1999
[2] resigned on 3.5.2000
[3] joined as Ernet Project Assistant from 1.6.2000
[4] resigned on 30.6.2000
[5] joined on 22.1.2000
[6] resigned on 19.11.1999
[7] joined on 3.4.2000
[8] term ended on 30.4.2000
[9] resigned on 31.10.1999
[10] resigned on 30.6.2000
[11] joined on 8.5.2000
[12] joined on 19.11.1999 and left on 2.3.2000 on health grounds

1.5 Ph.D. Students

Name	*Userid*
MATHEMATICS	
Paramita Das	pdas
Shamindra Kumar Ghosh	shami
Gyan Prakash	gyan
Rajesh, M.	rajesh
Surya Ramana, D.[1]	suri
Ravindra, G.	ravindra
Sabu, N.	sabu
Uma, V.	uma
PHYSICS	
Dutta Sreedar Babu	sbdutta
Subrata Bal	subrata
Balaji, K. R. S.	balaji
Bobby Vinod Kr. Ezhuthachan[2]	bobby
Arundhati Dasgupta[3]	dasgupta
Tarun Kanti Ghosh	tkghosh
Jayajit Das[4]	
Pushan Majumdar	pushan
Manoj, G.	manoj
Murugesh, S.	mgesh
Rajesh, V.[5]	chinta
Samik Das Gupta[6]	samik
Santosh Kumar	sant
Subhasis Sinha	subhasiskhan
Souman Basak[7]	soumen
Sumithra, S. R.	sumithra
Naveen Surendran	naveen
Swarendu Sarkar[8]	swaren
Suneeta Varadarajan	suneeta
THEORETICAL COMPUTER SCIENCE	
Madhusudan, P.	madhu
Meenakshi, B.	bmeena
Srinivasa Rao, S.	ssrao
Suresh, S. P.	spsuresh

[1] term ended on 31.12.1999
[2] joined on 2.8.1999
[3] term ended on 31.8.1999
[4] at R.R.I.Bangalore
[5] joined on 2.8.1999
[6] joined on 1.1.2000
[7] joined on 19.8.1999
[8] joined on 2.8.1999

1.6 Administrative Staff

Ramakrishna Manja	Chief Administrative Officer
Jayaraman, R.	Administrative Officer
Krishnan, S.	Accounts Officer
Santhanagopalan, K. S.	Librarian
Sampath, N. S.	Junior Administrative Officer
Gayatri, E.	Junior Accounts Offier
Mohan, S.	Junior Engineer (Electrical)
Arangarajan, R.	Junior Engineer (Civil)
Venkatesan, G.	Deputy Librarian

Amulraj, D.
Ashfack Ahmed, G.
Balakrishnan, A. R.
Balakrishnan, J.
Elumalai, G.
Ganapathi, R.
Geetha, M.
Indra, R.
Janakiraman, J.
Moorthy, E.
Munuswamy, 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.
Sankaran , K. P.
Selvaraj, M.
Tamil Mani, M.
Usha Devi, P.
Usha Otheeswaran
Vasudevan, T. V.
Varadaraj, M.
Venugopal, T.

Chapter 2

Academic Activities

2.1 Summary of Research

2.1.1 Mathematics

Algebraic Geometry

The study of the compactification of moduli spaces of vector bundles on a nodal curve has progressed further. In view of the recent results of I.Kausz (preprint: math.AG/9910166), several new questions have arisen. Efforts are on to resolve these along with the old questions about the moduli spaces that were constructed earlier (generalizing the work of D.Gieseker).

In order to verify Bloch's conjecture for surfaces, M. Green proposed a "higher" Abel-Jacobi homomorphism. However, C. Voisin showed that Green's construction does not capture all cycles. Several examples, which are easier than those of Voisin and which explain why Green's construction does not work, were constructed.

The above work and a prior study (conducted at the Institute) of M. Saito's theory of mixed Hodge modules led to a new definition of "higher" Abel-Jacobi maps and more general cycle invariants [M:BiPR]. It was shown that the arithmetic cycle conjecture of Beilinson and Bloch would imply the geometric conjecture of Bloch. (These results have also been obtained independently by M. Asakura and M. Saito.)

A host of examples of extreme cases, where the arithmetic conjectures of Beilinson and Bloch have not been verified, were constructed using a result of M. Terasoma. The general indicators seem to be that it is "easier" to detect arithmetically defined cycles using l-adic cohomology rather than intermediate Jacobians, as proofs for the latter require non-rationality of certain algebraic integrals.

Examples were obtained to show that the hypothesis in the arithmetic conjectures of Beilinson and Bloch are tight. In particular, a host of examples to construct cycles defined over fields of transcendence degree one that are *not* detected by intermediate Jacobians were established. This generalises earlier work by C. Schoen and M. V. Nori.

The Hodge conjecture for a general Prym variety was proved [M:P2].

Analysis

Work on some fixed point theorems led to obtaining improved convergence rates for a class of maps in Banach spaces.

Differential Equations

Several optimal control problems with distributed or boundary control were considered [M:Ke3]. In each of them, the cost of the control in the objective function is multiplied by a factor ε, which tends to zero. Hence, the problem is termed a low cost control problem. In certain cases, the state equation, which is a second order elliptic boundary value problem, also involves a differential operator with highly oscillating coefficients. The asymptotic behaviour is studied. It is shown that, as ε tends to zero, the state variable converges strongly, in the appropriate topology, to the solution of a variational inequality and the cost functional also converges suitably. The convergence of the optimal control occurs in a much weaker topology. When the norms of the state variable and the control occurring in the objective functions are on the same function space, it is shown that the asymptotic behaviour described above is valid even when the state equation has oscillating coefficients. If they are on different spaces, then one is able to pass to the limit only when the differential operator in the state equation is independent of ε. An exception to this rule is when the set of controls is a bounded convex set. In that case, even the control behaves well in the limit and in the case of a ball, one even has strong convergence of the optimal control.

Mathematical Physics

The Anderson model with decaying randomness was studied and the existence of a mobility edge for a class of random potentials decaying in some directions in higher dimensions was proved [M:Kr1].

A random model in one dimension with the interactions random and diagonal in a wavelet basis was studied and the existence of pure point spectrum low energy regime was established [M:Kr2].

Number Theory

Some results on the gaps between the ordinates of poles of the quotient of a certain class of Dirichlet series were obtained. These had some interesting applications to the study of the Riemann zeta-function.

Results were also obtained on the localization of zeros of functions in the Selberg class [M:S]. In particular, it was shown that if f and g are two functions in the Selberg class and if *degree* $f \geq$ *degree* g, then every interval $[T, T + c \log\log T]$, contains a zero of f which is not a zero of g, where $T \geq T_0$(a large positive constant) and c is a large positive constant.

A new proof of congruence properties of generalized Bernoulli numbers has been obtained.

It was proved that the Diophantine equation

$$\frac{a_1}{y_1} + \frac{a_2}{y_2} + \cdots + \frac{a_n}{y_n} = 0,$$

where a_i's are non-zero integers and y_i's are n unknown variables, is regular if, and only if, for some non-empty subset I of $\{1, 2, \cdots, n\}$, $\sum_{i \in I} a_i = 0$. In particular, $1/x + 1/y = 1/z$ is regular. Also, if an integer $f(r)$ is defined to be the largest integer such that when the set $\{1, 2, \cdots, f(r) + 1\}$ is partitioned into r parts in any manner, one of the cells contains a solution of $1/x + 1/y = 1/z$, then it was shown that $f(r + 1) \geq 2f(r) + 1$ and $f(3) \geq 191$. In particular, for $r \geq 3$, it follows that $f(r) \geq 2^{r-3}(192) - 1$ [M:T4].

A special case of a conjecture of Borwein and Chow on cyclotomic polynomials was established [M:T3].

Operator Algebras

Various details regarding Ocneanu's construction of a Topological Quantum Field Theory from a 'finite-depth subfactor' were worked out [M:Mono1].

The ongoing investigation of the paragroup associated to a subfactor was continued and it was shown how the so-called fusion rules for the bimodules associated to the subfactor could be directly read off from the paragroup. In the process, other results of independent interest were obtained. For instance, a proposition regarding what might be called 'One $*$ flatness', which turns out to be equivalent to the customary axiomatisation of flatness of the connection on a paragroup (which might be termed 'Four $*$ flatness' in analogy) was proved [M:KoSu2].

A striking 'obstruction' to two graphs arising as the pair of dual principal graphs of a subfactor was obtained. It was shown that the associated adjacency matrices, when regarded as self-adjoint operators on the corresponding ℓ^2 spaces, have 'mutually absolutely continuous spectra on the complement of 0' [M:KoSu3].

Finishing touches were put on an ongoing project concerning *actions of hypergroups* [M:Su5]. Here a pleasant geometric reformulation of what it means for a 'Hermitian signed hypergroup' to admit an action with specified 'multiplicities of characters' was obtained. Using this description, it was shown that it is possible for a finite hypergroup to admit infinitely many pairwise inequivalent *-actions on a finite set.

Some progress was made ([M:Su6]) on the problem of whether the left-regular representation of an infinite-dimensional fusion algebra can admit finite-dimensional subrepresentations. It was shown that this is impossible for the fusion algebra arising from the irreducible representations of a compact Lie group; a counterexample to the problem as stated in its full generality was also obtained.

2.1.2 Physics

CLASSICAL AND QUANTUM MECHANICS

Nonlinear Dynamics, Solitons and Chaos

A general relationship between the "Fermi-Walker" and "incompatibility" phases for a moving space curve of arc length s is derived. It is shown that the (linear) Schrödinger equation with a potential V(s,t) can be geometrically visualized as a moving curve whose local Fermi-Walker phase is given by $-(\partial V/\partial s)$. In contrast to the case of the cubic nonlinear Schrödinger equation, a certain non-commutativity plays a crucial role in establishing this visualization[P: Ba1].

The lowest-lying excitation of a classical XY spin chain, in the presence of a symmetry breaking magnetic field is studied. Extremizing the energy of this system leads to a two-dimensional nonlinear map, whose allowed phase space shrinks with increasing field in a nontrivial manner. The excitation with energy closest to the ground state is identified, for a given magnetic field. The variation of the energy of this excitation with the magnetic field is then studied. Interestingly, sharp jumps occur at a certain primary critical field, as well as certain secondary critical fields. These jumps are shown to appear whenever the corresponding spin configurations become commensurate with the natural period of the underlying lattice. These results are interpreted, highlighting the effects of both spatial chaos as well as the field induced transitions that are inherent in this system[P: Ba2].

By using appropriate change of variables, it had been shown by us in earlier work that a wide class of moving curves can be mapped to an equation that has the same form as the Belavin-Polyakov equation. Exact multi-twist solutions have been obtained for this nonlinear equation and applied to certain continuum magnetic models[P: Ba3].

The O(3) nonlinear sigma model on a wide class of curved surfaces is studied. A generalization of the well known Bogomol'nyi inequality is obtained. Interesting effects that emerge in this model due to the interplay between nonlinearity and geometry are discussed[P: Ba4].

An extended formulation for moving curves is presented to show that in addition to the usual Hasimoto function which is known to satisfy certain soliton equations, there exist two other complex functions which also satisfy them. Using the dependence of these functions on the geometric parameters of the curve, it is shown that *three* distinct classes of curve evolution get associated with a given integrable equation. This demonstrates that such an equation has a much richer underlying geometric structure than hitherto envisaged. Application to the nonlinear Schrödinger equation is discussed[P: Ba5].

The computational capability of networks of chaotic elements was demonstrated recently. Here new approaches are proposed to chaotic computing, by introducing direct implementation of the logical AND, OR, NOT and XOR operations, particularly employing multi-dimensional chaotic elements. This direct and flexible implementation of the most basic functions can serve as simple and cost effective key ingredients of an extremely fast general-purpose computing system. Such logical operations can also serve flexibly as the basis for bit by bit arithmetic addition and as a basic component of computer memory[P:Sinh3].

Investigations have been carried out on the spatiotemporal dynamics of two dimensional coupled map lattices, in the strong coupling phase, evolving under updating rules incorporating varying degrees of asynchronicity. Interestingly, one can observe that parallel updates never allow synchronisation among the sites, while asynchronicity has the effect of opening up windows in parameter space where the synchronised dynamics gains stability. As asynchronicity increases, the parameter range supporting synchronisation gets rapidly wider. Detailed numerics, including bifurcation diagrams and patterns formed en route to synchronisation, are reported. A mean-field analysis of the system accounting for the stability of the spatiotemporal fixed point under asynchronous updates is also presented[P:Me1].

Mathematical Methods

Mathematical aspects and physical relevance of coherent states of quadratic nonlinear algebras have been analyzed ([P:J1] and [P:J4]).

Application of Adomian's decomposition method to second order linear differential equations, taking correctly into account the behaviour of the solutions near the singular points, is revisited and it is shown how the classical results on the special functions of mathematical physics can be obtained in a very simple straightforward iterative process in this method[P:J3].

Certain two-term transformation formulas between basic hypergeometric series have been described by means of invariance groups. For transformations of non terminating ${}_3\phi_2$ series, and those of terminating balanced ${}_4\phi_3$ series, these invariance groups are symmetirc groups. For transformations of ${}_2\phi_1$ series the invariance group is the dihedral group of order 12. Transformations of terminating ${}_3\phi_2$ series are described by means of some subgroup of S_6, and the invariance group of transformations of very-well-poised non terminating ${}_8\phi_7$ series has been shown to be the Weyl group of a root system of type D_5 [P:Sr1].

Hypergeometric identities (or transformations) are derived systematically, using the Pochammer β integral representation for hypergeometric series. An algorithmic approach of this problem, using the HYP software package of C. Krattenthaler with Mathematica, has resulted in some new identities not found hitherto in literature. A q- generalization of these results is in progress.

The ratio of two contiguous functions of the type ${}_3F_2(1)$ has been recently represented as a continued fraction, using a Thomae transformation for non terminating ${}_3F_2(1)$, by R.Y. Denis and S.N. Singh. In view of the fact, that the Thomae transformation is a member of a group of 120 transformations, it is possible to imbed their result into a family of continued fractions. Work is in progress to this end and to deduce some of the known results for continued fractions for special functions from this family.

New expansions for terminating balanced ${}_4F_3(1)$ series have been derived by Gasper in the $q \to 1$ limit from the corresponding ${}_4\phi_3$ results of his. Since these ${}_4F_3(1)$ series play a key role in the quantum theory of angular momentum (where they are related to the 6-j coefficient). It is shown that one of these new identities for the ${}_4F_3(1)$ can be derived from a classical one satisfied by the 6-j coefficient. By changing one 'phase factor' this identity becomes a well-known expansion for the 9-j coefficient.

Optics

A coherent rotationally symmetric two-dimensional beam is essentially one-dimensional in content: it is fully determined by the one-dimensional sample along a diagonal of the circularly symmetric field distribution in a transverse plane. Linear transform which reconstructs, for such beams, the four-dimensional Wigner distribution of the full two-dimensional beam from the two-dimensional Wigner distribution of the one-dimensional sample are given. The practical importance of this linear transform or reconstruction algorithm stems from this fact: while two-dimensional Wigner distributions are fairly easy to measure optically, four-dimensional Wigner functions cannot be measured directly, owing to limitation on the dimensionality of the physical space in which optical experiments are carried out. It is also explained why the reconstruction algorithm does not apply to beams which are partially coherent in the spatial sense[P:S7].

Wigner's quasi-probability and related functional and operator methods of quantum mechanics have recently played an important role in optics. An analysis of some of these developments is undertaken from a unified point of view. The symmetry structures underlying the ray and wave approaches to paraxial optics are explored, and the manner in which the Wigner phase space representation captures the merits of both approaches is brought out. A fairly self-contained analysis of the second or intensity moments of general astigmatic partially coherent beams and their behaviour under transmission through astigmatic first order optical systems is presented. Geometric representations of the intensity moments which render the quality parameters or polynomial invariants manifest are discussed, and the role of the optical uncertainty principle in assigning unbeatable physical bounds for these invariants stressed. A simple scheme for measurement of the intensity moments is proposed[P:S4,P:S8].

Fractionalization of the 2-dim Fourier transform is analysed, starting from the reasonable and minimal premise that repeated application of a fractional Fourier transform sufficient number of times should give back the two-dimensional Fourier transform. There is a qualitative increase in the richness of the solution manifold, from U(1) in the 1-dim case to U(2), the group of 2×2 unitary matrices [rather than simply to U(1) $\times$ U(1)]. Parameterization of this four-parameter manifold of fractional transforms is accomplished through two powers or orders running over the torus $\mathcal{T}^2 = S^1 \times S^1$ and two parameters running over the 'Fourier sphere' S^2. Details of the spectral representation for the fractional transform are presented: the eigenvalues are shown to depend only on the orders or $\mathcal{T}^2$-coordinates, and the eigenfunctions only of the type or S^2-coordinates. Fractional transforms corresponding to special points on the Fourier sphere have the Hermite-Gaussian beams and the Laguerre-Gaussian beams as their eigenfunctions, while that corresponding to a generic point has SU(2) coherent states of these beams as its eigenfunctions. The integral kernels are displayed as oscillating Gaussians. It is noted that every $Sp(4, \Re)$ first order system is essentially a fractional Fourier transformer[P:S9].

Phase space description of the Laguerre-Gaussian modes is studied, bringing out the connection between these modes and the Hermite-Gaussian modes. The underlying phase space symmetries are exploited to derive a closed form expression for the Wigner distribution function of Laguerre-Gaussian modes. This expression turns out to be as compact as the familiar one for the Hermite-Gaussian modes. Our closed form expression is contrasted with an earlier expression, due to Gase, involving a four-fold summation[P:S10].

A class of beams that are both partially polarized and partially coherent from the spatial standpoint is studied. These beams are characterized by a correlation matrix whose elements have the same form as the mutual intensity of a Gaussian Schell-model beam. Those beams that would appear identical to ordinary Gaussian Schell-model beams in a scalar treatment are considered. After establishing some inequalities that limit the choice of the matrix parameters, we study the main effects of propagation. Starting from the source plane in which the beam is assumed to be uniformly polarized, we find that in the course of propagation the degree of polarization generally becomes non-uniform across a typical section of the beam. Furthermore, we find that the intensity distribution at the output of an arbitrarily oriented linear polarizer is Gaussianly shaped at the source plane whereas it can be qualitatively different at other planes[P:S11].

The harmonic oscillator coherent states exhibit completeness at two different levels. At the state vector level every Hilbert space vector can be expressed as a linear combination of the coherent states (this expansion is not unique, due to over-completeness). More importantly, at the operator level every Hilbert space operator can be realized as a linear combination of the rank one projections over the coherent states, and this completeness is known as the *diagonal representation theorem*. While completeness of generalized coherent states (Perelomov) at the state vector level follows from Shur's lemma, their completeness at the operator level has remained an unsolved problem. The Clebsch-Gordan theory and the reciprocity theorems associated with induced unitary group representation are exploited to derive necessary and sufficient conditions for the possibility of diagonal representation for operators in any family of generalized coherent states associated with an unitary irreducible representation of a (compact) Lie group. Applications to several examples involving $SU(2)$, $SU(3)$, and the Heisenberg-Weyl group are presented, showing that there are simple examples of generalized coherent states which do not meet these conditions. Our results are relevant for phase-space description of quantum mechanics and quantum state reconstruction problems[P:S12].

CONDENSED MATTER PHYSICS

The 41 meV resonance peak observed in neutron scattering experiments on YBCO is argued to be an effect of (rather than a cause of) high T_c superconductivity, through the interpretation of various experimental results as well as from theoretical arguments[P:Bas1]. The principle of "Valence bond amplitude maximization" (VBAM) is an unifying principle that underlies various ordering tendencies in the undoped and doped cuprates[P:Bas2]. This principle is shown to be valid for the undoped Mott insulator and shown to be approximately true for the doped Mott insulator. It shows that low energy charge stripe and spin stripe phenomena as well as the presence of low energy spin fluctuations do not provide a mechanism for superconductivity but inhibit it.

The origin of the spin stripe instability seen in LSCO is discussed using a Ginzburg-Landau approach. A special nearly temperature-independent magnetic response of the normal state of LSCO is argued to be responsible for the onset of quasi-static spin stripe order together with superconducting order[P:Bas3].

Important developments in the RVB theory of superconductivity starting from P.W. Anderson's path breaking work in Jan 1987 have been analysed. It is argued that during 1987 "a correct and sophisticated" solution to the mechanism of superconductivity has been given by Anderson and collaborators[P:Bas4,Bas5,Bas9].

A new phase diagram for disordered low-T_c type-II superconductors has been proposed. This phase diagram suggests, contrary to previous ideas, that the relatively ordered phase with power-law decay of translational correlations obtained at low temperatures in a disordered flux solid melts first into a glassy, intermediate state before undergoing a final transformation into a liquid. This proposal rationalizes a large body of data relating to anomalies in the peak effect regime of 2H-$NbSe_2$ [P:Men1].

It is proposed that the anomalies observed experimentally in the peak effect regime of 2H-$NbSe_2$ derive from the phenomenon of "disorder-induced phase coexistence". It is argued that *on* a first-order phase coexistence line separating two phases, the system can minimize its free energy in the presence of disorder more effectively. It can do this by choosing, locally, between either of the two phases, depending on the coupling of the disorder to the *order parameter* of the transition. Such increased stability may account for the abrupt rise in critical current densities observed and suggests that peak effects should be associated with all first-order phase transitions in vortex systems[P:Men4].

The interaction of active membranes with external confining walls is currently being studied. The possibility of magnification of fluctuations through the presence of the wall is examined in the context of new *relevant* terms in the coarse-grained free energy of such a system which have been introduced recently.

The spatial structure of persistent regions in various coarsening systems has been studied[P:Ma1]. In one dimension, a scaling theory based on Independent Interval Approximation has been developed and it was shown that the persistent sites form a fractal[P:Ma2]. The study has been extended to higher dimensions using finite size scaling techniques[P:Ma3].

The dependence of STM tunnel current on the extent of coverage is considered for a metallic adlayer in an electrochemical environment. Apart from leading to a two-dimensional band formation in the monolayer regime, the metalization of an adsorbate layer results in a progressive desolvation of the adspecies. As the associated energy change is a few electron volts, the effect of coverage variation is substantial on the current magnitude, even if the potential difference between the electrode and the STM tip is kept constant. The potential of a tip immersed in an electrolyte can also be varied only in a narrow range. This makes it difficult to access the adsorbate electronic levels in an STM study. It is demonstrated here that for a specific range of coverages, it is possible to obtain information regarding the adsorbate density of states. The formalism is finally applied to STM studies of a copper layer chemisorbed on a gold surface. The present study is relevant for the identification of the adsorbate at an electrochemical interface[P:Mi1].

Shape transformations in Skyrmion lattices near the $\nu = 1$ quantum Hall ground state have been studied. The low energy dynamics of skyrmionic excitations about the ground state has been analysed using a non-linear sigma model with Zeeman and Coulomb interactions. Shape transformations were studied on a face centered rectangular lattice as a function of the filling factor.

Fluctuations in Bose-Einstein condensates pose an interesting problem since below the critical temperature the description through the grand canonical ensemble leads to contradictions. The problem is especially interesting for finite systems with interactions as is the case

with the recent experiments on BEC. A consistent canonical and micro-canonical description of fluctuations in interacting, finite Bose and Fermi systems is being developed.

Attempts are being made to find interacting systems which may be described by fractional exclusion statistics (FES) in higher dimensions, especially two dimensions, in order to understand the origins of FES[P:Mu2]. While the precise nature of the interaction which leads to FES is not obvious, it seems clear that one needs very short range interactions when viewed from mean-field point of view. This was demonstrated by doing a Thomas-Fermi calculation as well as a self-consistent Hartree-Fock calculation.

A system of confined fermions with interactions is analysed in two-dimension within self-consistent Thomas-Fermi(TF) method. While the formalism may be developed for arbitrary forms of two-body interactions, it is shown that the TF model with logarithmic interaction is in fact an exactly solvable model. Further, it is shown that the quantum corrections to the Thomas-Fermi energies reproduce the main features, namely the shell effects, seen in recent experiments[P:Mu3].

The collective magnetoplasmon excitations in a quantum dot containing finite number of electrons in the high magnetic field limit are investigated. The electrons in the lowest Landau level and neglect mixing between the higher Landau levels are considered. The dispersion relation of these edge modes are estimated following the energy weighted sum-rule approach. In this finite size system the edge magnetoplasmon modes have different multipolarities (or angular momentum l). Their dependence on the magnetic field and on the system size is investigated. With increasing magnetic field, energy of these collective modes decreases and in the bulk limit they become gapless. The breathing mode of a dot in the presence of a strong magnetic field is also considered, and the energy of this mode approaches the cyclotron frequency $\hbar\omega_c$[P:Su1].

BIOLOGY

Proposals for two control strategies for achieving desired firing patterns in a physiologically realistic model Hippocampal neuron were made. The techniques are powerful, efficient and robust, and we have applied them successfully to obtain a range of targeted spiking behaviors. The methods complement each other: one involves the manipulation of only a parameter – the applied soma current; and the other involves the manipulation of only a state variable – the membrane potential. Both techniques have the advantage that they are not measurement intensive as just one variable needs to be monitored to implement control, and further, the schemes do not involve extensive run-time computation [P:Sinh7].

The projection of physical objects (stationary and moving) onto the perceptual space is a subject of much investigation. A non-Euclidean perceptual space has been suggested by Luneberg in 1947 in his analysis of binocular depth perception. This is further strengthened by Zhang and Wu in 1990 in their investigation using Reichardt motion detectors. Using these, we have developed a formalism for perceptual space. Here, the transformation from real to perceptual space is given by a generalized covariant tensor. The affine connection for the perceptual space is identified. Using this and the notion of parallel transport, we prove that closed loops in real space imply closed loops with the same orientation in the perceptual space[P:P1].

PARTICLE PHYSICS PHENOMENOLOGY

Neutrino Physics and CP Violation

In the area of neutrino masses and mixings a novel and simple approach was developed to generate large flavor mixings between any two active neutrinos. This effect can be realised as a consequence of the radiative corrections to the neutrino masses in the flavor basis. The scheme was then extended to a realistic three flavor framework and showed that this approach is indeed feasible at the experimental level. This scheme is in agreement with all the current existing data, and demands no extra symmetry impositions and hence is a robust method for understanding the neutrino anomaly. Investigations are underway on the issue of the relative CP parities between Majorana neutrino masses and its implication to current neutrino data. Issues regarding the structure of high scale physics and stability of mixing angles between neutrino flavors are also studied. Another aspect of these leptons namely whether they are Dirac(have an antiparticle) or Majorana(its own antiparticle) through examining the propagation/evolution of a given flavor in an external magnetic field was also studied and this test at the moment is experimentally difficult due to the presence of matter effects, which are currently avoided. Any future experimental test of this scheme, which can circumvent the matter effects, will place the proposal as an unique and the only other unambiguous test, besides the neutrinoless double beta decay searches. In continuation of the quest to pinpoint the nature of the neutrinos, Work is in progress on the Weiler mechanism for the ultra high energy cosmic rays, which are conjectured to originate from the predominant s-channel neutrino annihilation process.

Starting from a mass matrix of three inequivalent mass-degenerate Majorana neutrinos, a model of mass splitting that accounts for the solar and atmospheric neutrino oscillations is constructed. The model is consistent only with the large-angle MSW solution for the solar neutrinos. (It turns out that this is the *only solution not ruled out* by the most recent superkamioka data.) Further, this model requires a nonzero effective electron-neutrino mass for neutrinoless double β decay close to the present experimental upper limit of 0.2 eV[P: A1].

A new and novel synthesis is proposed for all existing neutrino oscillation data, assuming four neutrinos that includes a singlet or sterile neutrino of a few eV heavier than the other three. The latter may decay into a massless Goldstone boson (the singlet Majoron) and a linear combination of the doublet antineutrinos. The decay allows one to evade the earlier experimental constraints and this scenario can be confronted in future experiments. In view of the latest atmospheric and solar neutrino data, this is the *only viable* four-neutrino model now left[P: R1].

Large extra dimensions have been recently invoked to solve a number of problems in High Energy Physics. They are used to solve the problem of tiny neutrino masses including a light sterile neutrino. A specific realization of the only viable phenomenological neutrino model (mentioned above) has been constructed[P: R2].

The hot issue in flavor physics is to search for CP violation in B meson systems. In this regard, attempts to directly measure the QCD corrected Wilson couplings in rare semileptonic b-quark decays has been proposed. Studies have been conducted for the standard CP asymmetries with and without the additional "beyond the standard model interactions" in these rare decays. Interesting spin-spin correlations studies between the charged tau leptons

will give invaluable information on the absorptive part of the Wilson coupling. [P:B1, P:B2, P:B3]

The work on the effect of flavour mixing and consequent neutrino oscillations on the neutrino fluxes from stellar collapse has now been extended further and a full scale phenomenological analysis has been carried out. The analysis in the frame-work of three neutrino (and anti-neutrino) species has been further extended to carefully study the non-adiabatic effects, if any due to high dense matter, during the propagation of neutrinos. The analysis takes into account the constraints placed on the masses and mixings by the present understanding of the solar, atmospheric and laboratory experiments. More importantly the analysis was also extended to include a fourth, sterile, neutrino species in order to accommodate the results from the Los Alamos experiment which claims an unambiguous result for ν_μ to ν_e oscillation. Unlike other neutrino puzzles like the solar and atmospheric neutrinos problems, the neutrinos from stellar collapse involve all neutrino and antineutrino flavours. The signatures from collapse therefore also carry with them information about mixing, number of flavours apart from information about the stellar core itself [P: D1, P: D2]. The necessary parametrisations for the neutrino mixing matrix was evolved in consistent with available experimental information as part of the neutrino working group during WHEPP-6.

The $b \to d$ penguin amplitude receives contributions from internal u, c and t-quarks. It was shown that it is impossible to measure the weak phase of any of these penguin contributions without theoretical input. However, it is possible to obtain the weak phase if one makes a single assumption involving the hadronic parameters. With such an assumption, one can test for the presence of new physics in the $b \to d$ flavour-changing neutral current by comparing the weak phase of $B^0_d - \bar{B}^0_d$ mixing with that of the t-quark contribution to the $b \to d$ penguin[P:Si1,Si2].

The short-distance Hamiltonian describing $b \to s(d)e^-e^+$ in the standard model is used to obtain the decay spectrum of $\bar{B} \to K^-\pi^+e^-e^+$ and $\bar{B} \to \pi^-\pi^+e^-e^+$, assuming the $K\pi$ and $\pi\pi$ systems to be the decay products of K^* and ρ respectively. Specific features calculated are (i) angular distribution of K^- (or π^-) in the $K^-\pi^+$ (or $\pi^-\pi^+$) centre-of-mass frame; (ii) angular distribution of e^- in the e^-e^+ c.m. frame; and (iii) the correlation between the meson and lepton planes. CP-violating observables obtained by combining the above decays with the conjugate processes $B \to K^+\pi^-e^-e^+$ and $B \to \pi^-\pi^+e^-e^+$ were also derived[P:Si3].

A new method for extracting weak, CP-violating phase information, with no hadronic uncertainties, from an angular analysis of $B \to V_1V_2$ decays, where V_1 and V_2 are vector mesons is presented. The quantity $\sin^2(2\beta+\gamma)$ can be cleanly obtained from the study of decays such as $B^0_d(t) \to D^{*\pm}\rho^\mp$, $D^{*\pm}a_1^\mp$, $D^{*0}K^{*0}$, etc. Similarly, one can use $B^0_s(t) \to D^{*\pm}_s K^{*\mp}$ to extract $\sin^2\gamma$. There are no penguin contributions to these decays. It is possible that $\sin^2(2\beta+\gamma)$ will be the second function of CP phases, after $\sin 2\beta$, to be measured at B-factories[P:Si6].

QCD

Power Corrections to the leading twist results of perturbative QCD are being studied, specifically in the context of event shape variables like the thrust. The work of the Milan group (Dokshitser, Webber, et. al) gives a systematic methodology of analytically continuing the strong coupling constant to low values of Q^2 using a spectral representation for $\alpha_s(Q^2)$. They use it to calculate the leading power corrections to various measurables like hadronic

decay widths, structure functions, event shapes in jet cross sections etc. They fit it to data to estimate one of the free parameters in their analysis (called the Milan factor). However calculation of the power corrections, particularly in event shapes like the thrust by including the effect of quark masses was carried out 13 years before the work of the Milan group (R. Basu, Phys. Rev. D 29, 2642 (1984)). The recent data from L3 and other groups along with the earlier data is being renalysed after including quark mass corrections, to get a fresh estimate of the Milan factor after including these additional corrections, in particular, the c and b quark masses. It appears from preliminary analysis that there is a substantial shift in the value of the Milan factor and also in estimates of α_s. [P:Basu1]

The important problem of confinement in QCD is addressed to by concentrating on the infrared region. Extending the earlier work of proposing suitable $SU(3)$ field configurations in this region exhibiting dual Meissner effect (without quarks), a string action is derived. This action corresponds to the rigid string action of Polyakov.

In order to understand the geometry of the string world sheet pertaining to confining strings, the Willmore functional for surfaces immersed in Riemann space is studied under normal fluctuations of the world sheet. The equation of motion is then compared with that of the QCD string and a relationship among the string tension, rigidity of the string worldsheet and the curvature of the worldsheet is derived[P:P2].

The confinement problem is further studied including the quarks in the fundamental representation. The effective dual action is derived and this exhibits dual Meissner effect along with Biot-Savart energy term. A correspondence with Schwinger's model of hadrons is established[P:P3].

Analysis has been conducted on the Q^2 dependence of the spin dependent density distribution functions and hence the spin dependent properties of nucleon structure functions from deep inelastic scattering data [GGI00]. This is very relevant in view of new upcoming experiments such as the COMPASS at CERN and the possibility of a polarised machine at HERA and RHIC that will probe the spin structure of the nucleon and even nuclei[P: I1,P:I2].

There are large transverse polarisation asymmetries observed experimentally, that has remained unexplained so far. The usual wisdom in perturbative QCD yields tiny asymmetries, mainly due to the feature that parton transverse momenta are expected to be tiny. Mechanisms that can amplify the intrinsic finite transverse polarisation are under investigation. Soft mechanisms, which has to be necessarily non-perturbative input for effecting a possible scenario are being looked into.

QFT, Quantum Gravity, Blackhole, String Theory

A resolution for the fermion doubling problem in discrete field theories is proposed based on the fuzzy sphere and its Cartesian products. Its relationship to the Ginsparg-Wilson approach[P:G1,G2] is also brought out.

The important issue of whether supersymmetry is broken or not at finite temperature is addressed to by considering the enlarged thermal system including the heat bath using the

'doubled Fock space'. A super algebra is constructed and the total Hamiltonian for free fields is expressed as an anti-commutator of super charges. With this Hamiltonian and thermal vacuum $\mid 0(\beta) >$, mathematical possibilities are exhibited realizing super symmetry at finite temperature, in agreement with Van Hove[P:P4].

The exact formula derived earlier for the entropy of a four dimensional non-rotating black hole within the quantum geometry formulation of the event horizon in terms of boundary states of a three dimensional Chern-Simons theory, is reexamined for large horizon areas. In addition to the *semiclassical* Bekenstein-Hawking contribution proportional to the area obtained earlier, a contribution proportional to the logarithm of the area together with subleading corrections is found that constitute a series in inverse powers of the area[P:Ka1].

A spacetime with torsion produced by a Kalb-Ramond field coupled gravitationally to the Maxwell field, in accordance with a recent proposal is argued to lead to an optical activity in the form of birefringence in synchrotron radiation from cosmologically distant radio sources. This could *qualitatively* explain observational data from a large number of radio sources displaying such polarization asymmetry (after eliminating effects of Faraday rotation due to magnetized galactic plasma). Possible implications for heterotic string theory are also outlined[P:M1].

The question of how infalling matter in a pure state forms a Schwarzschild black hole that appears to be at non-zero temperature is discussed in the context of the AdS/CFT connection. It is argued that the phenomenon of self-thermalization in non-linear (chaotic) systems can be invoked to explain how the boundary theory, initially at zero temperature self thermalizes and acquires a finite temperature. Yang-Mills theory is known to be chaotic (classically) and the imaginary part of the gluon self-energy (damping rate of the gluon plasma) is expected to give the Lyapunov exponent. It is explained how the imaginary part would arise in the corresponding supergravity calculation due to absorption at the horizon of the black hole [P:K1]. Investigations are being carried out on further issues in this non-equilibrium process, both analytically and numerically. In particular attempts are made to understand the role of Hawking radiation and also the case of large angular momentum.

Type IIB supergravity in the presence of (Euclidean) D3 branes and nonzero self-dual B-fields is studied. It is point out that the Einstein frame metric is identical to the full geometry for D3 branes without B fields turned on. Furthermore, in a decoupling limit in which the theory is conjectured to be dual to noncommutative Yang-Mills theory, the entire Einstein metric remains intact, and in particular, is asymptotically flat. D-instanton solutions in this geometry is also constructed. It is shown that in the decoupling limit the D-instanton action agrees with the action of the corresponding instanton in the noncommutative Yang-Mills theory and is expressed in terms of the open string coupling. Some other aspects of this correspondence, which have unusual features because the underlying metric is asymptotically flat, are explored [P:K2].

Loop variable approach to string theory is being studied. One of the physical motivations was to relate gauge invariance in string theory to a local scale symmetry or renormalization group symmetry. Earlier work in loop variables involved the free theory - which was worked out in 1989. A proposal for the interacting theory was made at the 1996 Puri workshop. It had the same simplicity that the free theory had but there were some issues of consistency in defining space time fields. The gauge invariance is very simple in terms of loop variables

but it was not clear that a consistent set of transformation laws would emerge for space time fields from this. Also it was not clear whether the results would agree with perturbative on-shell string theory. It appears possible now to have consistent gauge transformations for space time fields and also it seems possible to show that the amplitudes agree with string theory on shell[P:Sa1].

D-branes on Calabi-Yau threefolds continued to be studied from various perspectives. The case where such branes corresponded to special Lagrangian sub-manifolds of the Calabi-Yau were studied in detail. It was shown that in the Landau-Ginzburg formulation of the problem (as also in the linear sigma model description), these corresponded to straight lines in the W-plane, with $ImW = 0$, where W is the superpotential appropriate to the particular Calabi-Yau manifold being studied. The general case of non-linear boundary conditions appropriate to such D-branes (known as A-type branes in the literature) were studied. This enabled a physics description of several special Lagrangian sub-manifolds described in the mathematics literature, including some in C^n described by Harvey and Lawson, as well as the case of the T^3 cycle in the quintic Calabi-Yau [P:Ja1].

In order to study the dependence of D-brane physics on the Kahler moduli of the Calabi-Yau manifold, a linear sigma model description of D-branes on such manifolds was formulated. Both A-type and B-type D-branes in the gauged linear sigma model were studied by considering worldsheets with boundary. The boundary conditions on the matter and vector multiplet fields were first considered in the large-volume phase/non-linear sigma model limit of the corresponding Calabi-Yau manifold, where it was found that one had to add a contact term on the boundary. These enabled the derivation of the boundary conditions in the full gauged linear sigma model, including the addition of the appropriate boundary contact terms, such that these boundary conditions have the correct non-linear sigma model limit. Most of the analysis was for the case of Calabi-Yau manifolds with one Kahler modulus (including those corresponding to hypersurfaces in weighted projective space), though possible generalizations were hinted at ([P:Ja2]).

The issue of arrow of time is studied within the context of general relativity with quantized Klein-Gordon field in curved space-time with Killing horizon. It has been shown that quantized matter fields in the presence of metrics with Killing horizon exhibit spontaneous time asymmetry by showing that one can realize either retarded or advanced (but not both) Green functions. Some phenomenological applications of this in the context of black holes and early universe are pointed out [P:An1].

The laws of black hole mechanics are sought to be extended to the case of "isolated horizons". A classification and most general characterization of these horizons is being carried out.

A new entropy bound, tighter than the standard holographic bound due to Bekenstein, is derived for spacetimes with non-rotating isolated horizons, from the quantum geometry approach in which the horizon is described by the boundary degrees of freedom of a three dimensional Chern Simons theory[P:Ka2].

The time-independent modes of a massless scalar field in various black hole backgrounds are studied, and it is shown that for these black holes the time-independent mode is localized at the horizon. A similar analysis is done for time-independent, equilibrium modes of the

five-dimensional plane AdS black hole. A self-adjointness analysis for this problem reveals that in addition to the modes corresponding to the usual glueball states, there is a discrete infinity of other equilibrium modes with imaginary mass for the glueball. It is suggested these modes may be related to a Savvidy-Nielsen-Olesen-like vacuum instability in QCD [P:G3].

A novel method, based on superpotentials is proposed for obtaining the quasi-normal modes of anti-deSitter black holes. This is inspired by the case of the three dimensional BTZ black hole, where the quasi-normal modes can be obtained exactly and are proportional to the surface gravity. Using this approach, the quasi-normal modes of the five dimensional Schwarzschild anti-deSitter black hole are computed numerically. The modes again seem to be proportional to the surface gravity suggesting that this may be a common feature of all anti-deSitter black holes [P:G4].

2.1.3 Theoretical Computer Science

Algorithms and Complexity

The probabilistic class ZPP(NP) has appeared in different results and contexts in complexity theory research. For example the result that if SAT has polynomial-size circuits then the polynomial hierarchy collapses to ZPP(NP) is based on a random sampling technique combined with the self-reducibility of SAT. A systematic study of lowness for ZPP(NP) was taken up [C:AK] and a number of new results (including the lowness of Graph Isomorphism and other group-theoretic problems for ZPP(NP)) were proved.

The notion of "instance complexity" developed by Ko, Orponen, Schöning and Watanabe captures the intuitive idea of hard individual instances for NP-complete problems. Fortnow and Kummer have shown, in 1995, that NP-complete problems have hard instances assuming P$\neq$NP. A different problem concerns the length of proofs in proof systems for propositional tautologies. The notion of hard tautologies was formalized using a nondeterministic generalization of instance complexity. It was then shown, under reasonable complexity-theoretic assumptions, that there are infinitely many propositional tautologies, each of which is hard to prove in any sound propositional proof system [C:AKMT].

The computational complexity of planarity testing was clarified by showing that planarity testing is hard for L, and lies in SL. This nearly settles the question, since it is widely conjectured that $L = SL$. The upper bound of SL matches the lower bound of L in the context of (nonuniform) circuit complexity, since L/poly is equal to SL/poly. Similarly,it was shown that a planar embedding, when one exists, can be found in FSL [C:AM].

It has been known for a long time now that the problem of counting the number of perfect matchings in a planar graph is in NC. This result is based on the notion of a pfaffian orientation of a graph [C:MSV]. (Recently, Galluccio and Loebl gave a P-time algorithm for the case of graphs of small genus.) However, it is not known if the corresponding search problem, that of finding one perfect matching in a planar graph, is in NC. This situation is intriguing as it seems to contradict our intuition that search should be easier than counting.

For the case of planar bipartite graphs, Miller and Naor showed that a perfect matching can

indeed be found using an NC algorithm. A very different NC-algorithm for this problem has been presented. Unlike the Miller-Naor algorithm, this approach directly uses the fact that counting is in NC, and it also generalizes to the problem of finding a perfect matching in a bipartite graph of small ($O(\log n)$) genus. It also rekindles the hope for an NC-algorithm to find a perfect matching in a non-bipartite planar graph. Along the way, the algorithm of Gallucio and Loebl was modified to show that counting the number of perfect matchings in graphs of small genus is in NC [C:MK].

Improved upper bounds have been obtained for several versions of the MaxSat problem [C:BR].

Our read-only memory algorithm for selecting an item of small rank from an unordered set (reported earlier) is applied to find a rank sensitive PRAM algorithm for selection [C:RR].

An exact characterization was obtained as to when the problem of finding a subgraph with a given hereditary property in an arbitrary given graph is fixed parameter tractable. More specifically, it is shown that if the hereditary property includes all cliques but not all independent sets or vice versa, then the subgraph finding problem is hard for the parameterized complexity class $W[1]$ and is fixed parameter tractable otherwise [C:KR].

A static dictionary data structure that answers membership and rank queries in constant time was obtained that takes $n \lg m + O(\lg \lg m)$ bits of space, where n is the size of the subset and m is the size of the universe. Using this structure, we obtained a representation of an $m-$ary cardinal tree with n nodes, that uses $n\lceil \lg m \rceil + 2n + o(n)$ bits of space and supports the tree navigational operations in constant time, when m is $o(2^{\lg n / \lg \lg n})$. For arbitrary m, we get a structure that takes the same space and supports all the navigational operations, except finding the child labeled i (for any i), in $O(1)$ time. Finding the child labeled i in this structure takes $O(\lg \lg \lg m)$ time [C:RS].

Distributed Systems – Automata and Logics

An automata theoretic model of navigation on the World Wide Web has been proposed. Constraints on navigation and search are phrased in a logical language, from which an automaton is synthesized. Interesting queries on navigation can then be answered using standard techniques in automata theory [C:LR].

Ongoing work on languages over series-parallel posets [C:LW1] has now been considerably generalized to languages over series-Σ algebras. Rational and regular languages are defined and shown to coincide (a Kleene theorem). It has also been shown that this expressive power equals that of algebraic recognizability (a Myhill-Nerode theorem). This generalizes the work of Thatcher and Wright from the 1960s. The first equivalence continues to hold when conditions such as associativity and commutativity are imposed on the term operations, but recognizability is weaker when one of the Σ-operations is associative [C:LW2].

Work has been continued on the problem of finding a decidable fragment of the distributed control-synthesis problem . Pursuing the idea of using local specifications, the class of architectures where this problem is decidable has been fully classified. This has led to the discovery of a game-problem where two players have incomplete information about each other, and yet the problem of finding the winner is decidable .

There were some attempts to simplify the classical proof of Safra for determinizing Büchi automata. Simple proofs of complementation and determinization through a common platform have been found. Though the conversions are not optimal, they could serve a pedagogical purpose. An investigation of trying to classify the class of infinite graphs over which the monadic second-order theory is decidable has been started.

A class of automata has been defined that models message based systems acting in finite state environments. These automata are used to solve the satisfiability and model checking problems of a propositional temporal logic interpreted on communication diagrams [C:MR].

Security is one of the primary issues in the study of Computer and Communication Systems. It encompasses confidentiality, integrity, and availability as applied to various information entities such as data, programs, computational resources, etc. Ongoing work attempts at modeling information security broadly, without reference to any particular layer. A model of security based on modal and temporal logic and automata theory has been proposed.

2.2 Publications

The following conventions have been adopted in the following list of publications: firstly, names of (co)authors who are not members of the Institute have been marked with a superscript *; secondly, in order to facilitate cross-referencing between this list and the 'summary of research' in Section 2.1, all entries in this list have been given a label and, finally, the entries are listed according to the alphabetical order of their labels.

2.2.1 Mathematics

[**M:Ba1**]
Balasubramanian, R. and Ramana, D. S.*
Additive complements of the squares.
To appear in *Comptes Rend. Acad. Sc.*, Canada.

[**M:Ba2**]
Balasubramanian, R., Kulkarni, S. H.* and Radha, R.*
Non-invertibility of certain almost Matheiu operators.
To appear in *Proceedings of the AMS.*

[**M:BaS1**]
Balasubramanian, R., Ramachandra, K.* Sankaranarayanan, A.* and Srinivas, K.
Notes on the Riemann zeta-function-III.
Published in *Hardy-Ramanujan J.*, **22** (1999), 23-33.

[**M:BaS2**]
Balasubramanian, R., Ramachandra, K.* Sankaranarayanan, A.* and Srinivas, K.
Notes on the Riemann zeta-function-IV.
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[**M:BaS3**]
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2.3 Conferences/ Workshops Held at IMSc

2.3.1 Workshop on Foundations of Mobile Computing

This international workshop was conducted at the Institute of Mathematical Sciences, Chennai, during December 16-17, 1999. The programme committee was co-chaired by Sanjiva Prasad (IIT, Delhi) and R. Ramanujam (IMSc).

The workshop was a satellite event to the conference *FST & TCS 1999*. Local organization was handled by Kamal Lodaya. A total of 67 participants registered for the workshop, with 14 of the participants from outside India.

The workshop had four tutorial talks:

- **Gerard Boudol**, INRIA, Sophia-Antipolis, France
  Mobility and migration, from a pi-calculus perspective
- **Andrew Gordon**, Microsoft Research
  A typed calculus of mobile computation
- **Jean-Jacques Lévy**, INRIA, Rocquencourt, France
  Translation of ambients into the join-calculus: a distributed implementation for ambients
- **Sanjiva Prasad**, IIT, Delhi
  Analysis of mobile network protocols using name-passing calculi

In addition, there were two contributed papers, a lecture on *Trends in pervasive computing* by **Rajeev Shorey**, IBM, India Research Centre, Delhi and a lively panel discussion moderated by **Martín Abadi**, Lucent Technologies.

2.3.2 WHEPP-6

The *Sixth Workshop on High Energy Physics Phenomenology (WHEPP-6)* was held at the Institute from January 3 to 15, 2000, with Rahul Basu as the convener. This series of Workshops in High Energy Physics Phenomenology (WHEPP) started in 1989. The workshops, which have been held (with one exception) every alternate year, attempt to bring together active particle phenomenologists from various universities and research institutes in India and abroad. The earlier workshops in the series have proved very useful, both in collecting people with common interests into groups which have successfully published several papers, and also as a common ground for persons of related fields to get together and widen their horizons of interest. WHEPP-3 was also held at the Institute, in 1993.

The workshops have stabilised into a two-week long activity, with special focus on topics of current discussed in parallel working group sessions. The workshop format consists of plenary talks, in the morning sessions of the first week, by experts in the field. The afternoons, as well as the entire second week, are devoted to working group sessions.

This year, the sub-fields that saw such focussed activity were that of neutrino and astroparticle physics, QCD, beyond the standard model, and collider physics (including B physics).

There were a total of 84 participants, including 16 speakers/participants from outside India. There were 22 plenary talks and about 16 scheduled working group talks, in addition to numerous other talks organised by each working group as part of their discussion sessions.

As in the preceding WHEPP (WHEPP-5) the proceedings of this workshop are being brought out as a special issue of *Pramana - Journal of Physics*, published by the Indian Academy of Sciences, Bangalore. The *Proceedings* are expected to appear in the July 2000 issue of *Pramana*.

2.3.3 Institute Seminar Week

The Institute Seminar Week was held from Monday, February 21, to Friday, February 25, 2000, from 11:30 to 12:50 in the Chandrashekhar Hall. The meeting was coordinated by Kapil Paranjape. The results of the survey conducted by Meena Mahajan regarding the previous seminar week were incorporated in the organisation of this program. As a result there were only four talks a day. The list of lectures is given below.

- **B. Sathiapalan**
  Chaos, black holes and gauge theories
- **Sudeshna Sinha**
  Controlling chaos
- **P. Majumdar**
  Quantum corrections to black hole entropy
- **N. D. Hari Dass**
  Banishing the continuum?
- **V. Raman**
  Time-space tradeoffs for selection
- **G. Rajasekaran**
  The problem of neutrino mass
- **G. Dutta**
  Neutrinos from stellar collapse – effects of flavour mixing
- **R. Simon**
  Quantum information
- **G. Baskaran**
  On the presence of Hopf term in 2d quantum Heisenberg antiferromanget
- **B. Meenakshi**
  Reasoning about message-passing
- **S. Kesavan**
  Low cost control problems
- **G. Rajasekaran**
  A new type of quantum field theory

- **V. S. Sunder**
  Spectra of graphs

- **T. R. Govindarajan**
  Non commutative geometry and quantum field theory

- **K. H. Paranjape**
  Algebraic cycles

- **K. Lodaya**
  Mobility and migration

- **A. K. Mishra**
  Differential calculus in non-commutative space and its Fock space representation

- **K. Srinivas**
  On the zeroes of Selberg class of functions

- **R. Shankar**
  Hydrodynamics of the quantum Hall fluid

- **Meena Mahajan**
  Finding and counting matchings

2.3.4 National Science Day

National Science Day is observed on February 28 every year. This year the activities were coordinated by Sudeshna Sinha. The programme was attended by about 15 students from science colleges in the city, and by several members of the Institute.

The day started with talks by Prof. N. D. Haridass (*How to tell Left from Right?*), Dr. Vijay Kodialam (*Theory of Invariants*) and S.P. Suresh (*What is Computer Science?*).

Another exciting event of the day was the slide show/ lecture by Prof. N. D. Hari Dass (IMSc) on the *Tale of Two Eclipses*. Later Dr. G. Subramonium showed the students the computer facilities and the library.

A major highlight of the programme was the **Science Quiz**. This quiz, which has become an annual feature of the National Science Day programme at IMSc, challenges the participants to find the scientific explanations behind phenomena we observe routinely in day-to-day life. It also probes their mathematical understanding and examines their appreciation of the bio-sciences. The first prize was won by one of the teams from Ethiraj College, and the second prize by one of the teams from Vivekananda College.

The programme concluded with a very informative special lecture on *Earth Studies with Celestial Assistance* by Prof. P. M. Mathews, Department of Physics, University of Madras, who also gave away the prizes to the winners of the science quiz.

2.3.5 Mini Symposium on *Motives*

A theory of "Motives" has been conjectured by A. Grothendieck, P. Deligne, S. Bloch, A. A. Beilinson and others as a way of solving numerous problems in algebraic geometry and arithmetic. A theory of "Motives" has been constructed by Madhav Nori of the University of Chicago. Various questions and extensions of this theory are as yet unresolved; but are likely to be resolved very soon.

A mini-sumposium was organised at the IMSc to study this theory for a period of four weeks from June 16, 2000 to July 14, 2000. Talks were given on all days by various lecturers from 10:00 to 13:30. This was followed by discussions in the afternoon from 15:30 to 17:30 and at night from 21:30 to 24:00. The discussion rooms in the old and new guest house were utilised for this purpose.

The participants were:

- **M. V. Nori** and **Kaj Gartz** from the University of Chicago, Illinois, USA.
- **V. Srinivas, C. S. Rajan, Arvind Nair** and **V. Trivedi** from the TIFR, Mumbai.
- **Prakash Belkale** from the University of Utah, Salt Lake City, USA.
- **Kapil Paranjape, Jishnu Biswas** and **G. V. Ravindra** from the IMSc, Chennai.
- **G. Dayal** from the CMI, Chennai.

The academic programme is outlined below.

- Representations of Diagrams - A general construction of a universal representation of a diagram in an Abelian category was presented by Professor Nori. This construction and the accompanying lemmas show that if indeed there is a category of motives then a small number of its properties determine it uniquely. This unique candidate can thus be referred to as *the* category of motives.
- The Basic Lemma - Professor Nori explained his "Basic Lemma" in its various forms. It implies further expected properties of the category of motives as constructed by him, such as the existence of tensor products, a theory of weights and relations with correspondences.
- Triangulated Categories - Some material on triangulated categories is required to understand the relations between Nori's abelian category and the constructions of Voevodsky. Lectures on triangulated categories and related topics were given by K. Paranjape, J. Biswas and A. Nair.
- Algebraic Singular Homology - The theory of Algebraic Singular Homology (also called Suslin homology) which has been developed by Suslin and Voevodsky was presented in lectures by Professor Srinivas. These lectures comprehensively explained this body of work.
- Other Theories of Motives - A survey of Voevodsky's construction of a triangulated category of motives was presented by Professor Belkale and Professor Srinivas. Voevodsky's main result (an "inversion theorem") which shows that all morphisms in his

category come from algebraic cycles is the principal missing ingredient in Nori's theory. The "classical" theory of Grothendieck motives was presented by C. S. Rajan.

- Hodge and D-Modules - A survey of the theory of D-modules and the work of Saito on (mixed) Hodge modules was discussed and presented in lectures by K. Paranjape.

- Vanishing Cycles - An important ingredient in any theory of motives will have to be a theory of degeneration. This is done for D-modules and sheaves by the theory of vanishing cycles. The work of Deligne and Verdier was presented by Professor Srinivas, and the work of Beilinson was presented by A. Nair.

- Open Problems - Professor Nori outlined a list of open problems in the area with indications of which results may be fit together to make the theory of motives complete. As yet neither Nori's abelian category of motives nor Voevodsky's triangulated category of motives is known to satisfy all the properties expected.

In conclusion, we feel that we have developed enough background material to now concentrate on individual aspects of Nori's theory of motives and yet co-ordinate these individual efforts. Thus the seeds for individual research and collaboration were sown as a result of this symposium.

2.4 Other Conferences/ Workshops Organized by IMSc

2.4.1 Workshop on Advances in Data Structures

This workshop was a satellite event of *FST & TCS* 1999, and it was held at the ICSR auditorium of I.I.T. Madras during December 11-12, 1999. The workshop had an impressive list of 8 international speakers, the names and the titles of their talks are listed below. This workshop, partially supported by National Board of Higher Mathematics, India, was attended by about 70 national and international participants. The workshop was organized by Ramesh Hariharan of I.I.Sc. Bangalore, Rajeev Raman of King's Collge, London, C. Pandu Rangan of I. I. T. Madras and Venkatesh Raman of IMSc.

- **J. Ian Munro**, University of Waterloo, Canada
  Succinct Data Structures
- **Paolo Ferragina**, University of Pisa, Italy
  String B-Trees: Theoretical Results, Algorithmic Engineering and Some Applications on XML Texts
- **Torben Hagerup**, University of Frankfurt, Germany
  Shortest Paths: Recent Developments
- **Peter Bro Miltersen**, University of Aarhus, Denmark
  Problems in Cell Probe Complexity (Some Open, Some Solved)
- **Gerth Brodal**, University of Aarhus, Denmark
  Regularities in Sequences
- **Sunil Arya**, Hong Kong University of Science and Technology, Hong Kong
  Expected-Case Complexity of Approximate Nearest Neighbor Searching
- **Guiseppe Italiano**, University of Rome, Italy
  Tuning the Cache Performance of a Local Search Algorithm for Graph Coloring
- **Rajeev Raman**, King's College, London, U. K.
  Cache Analysis of Sorting Algorithms

2.4.2 FST&TCS

FST & TCS (Foundations of Software Technology and Theoretical Computer Science) is an annual international conference organized by the research community in computer science in India (IARCS). The 19^{th} conference in this series was held at IIT Chennai from December 13 to 15, 1999. R. Ramanujam and Venkatesh Raman co-chaired the Programme Committee.

The conference had nearly a hundred submissions which were evaluated by at least three reviewers for each paper, and an international programme committee finally selected 30 papers for presentation at the conference. In addition, the conference had five *invited plenary talks*, by Professors Micha Sharir (Tel Aviv and New York Universities), Martín Abadi (Lucent Technologies), Jean-Jacques Lévy (INRIA Rocquencourt), Lila Kari (University of Western Ontario) and Seinosuke Toda (Nihon University). In two joint sessions with the International Symposium on Algorithms and Computation, Professor Monika Henzinger (Google) gave

a tutorial on *Web algorithmics*, while Professor Kurt Mehlhorn (Max-Planck-Institut für Informatik, Saarbrücken) gave an invited talk on *Algorithm engineering*. The conference had nearly 140 registered partcipants.

The conference included satellite events in the form of a pre-conference workshop on **Advances in data structures** (IIT, Madras, December 11-12, 1999), and a post-conference workshop on **Foundations of mobile computing** (IMSc, December 16-17, 1999), which had around 70 participants each.

The proceedings of the conference, edited by C. Pandu Rangan, V. Raman and R. Ramanujam and published in the Springer *Lecture Notes in Computer Science* series, Volume 1738, were distributed to the participants at the conference.

2.4.3 Recent Trends in the Quantum Hall Effect

A workshop titled "Recent Trends in the Quantum Hall Effect" was organised by The Institute of Mathematical Sciences, Chennai. It took place from April 17 to 21, 2000, at the Radio Astronomy Center, Udhagamandalam.

There were ten participants including seven theorists and three experimentalists. All participants were workers in the field. Participation was by invitation only.

There were review talks on:

- Analytic Methods in Composite Fermion Theory.
- Canted Phases in Double Layer Systems.
- Higher Landau Level Physics.
- Skyrmions in Quantum Hall Systems.

Apart from the review talks, there were intensive discussion sessions on various topics and seminars by participants on their research work.

2.5 Seminars

Seminars held at IMSc during 1999-2000

Date	Speaker Affiliation	Title
6-8-1999	Rajat Bhaduri McMaster Univ., Canada	Bose-Einstein Condensation of a Dilute Gas in a "Two-Dimensional" Atom Trap
6-8-1999	S.V. Nagaraj IMSc	Primality Based on Identity Checking
10-8-1999	S.V. Ramanan SUNY, Stonybrook	Intercellular Communication: Physiology and Biophysics–I
11-8-1999	G. Baskaran IMSc	Competition Between Stripes and Superconductivity
12-8-1999	S. V. Ramanan SUNY, Stonybrook	Intercellular Communication: Physiology and Biophysics–II
17-8-1999	R. Balasubramanian IMSc	Finding Roots of Succinctly Presented Polynomials
18-8-1999	A.P. Balachandran Syracuse University	Chiral Fermions on Fuzzy Sphere
19-8-1999	B. Basu-Mallick SINP, Calcutta	Symmetries and Exact Solutions of Some Integrable Haldane-Shastry-like Spin Chains
20-8-1999	B. Basu-Mallick SINP, Calcutta	Exact Spectrum and Partition Function of Supersymmetric Polychronakos Model
23-8-1999	V. John Rochester Univ.	Deep Inelastic Structure Functions From QCD
25-8-1999	Suresh Govindarajan IIT, Madras	Worldsheet Descriptions of D-Branes Wrapped on Supersymmetric Cycles

26-8-1999	Kapil Paranjape IMSc	Categories - A Theory of Everything
1-9-1999	Andreas Rosenschon University of Genova, Italy	A Lefschetz Theorem for Singular Varieties
2-9-1999	R.Balasubramanian IMSc	Cryptography and Number Theory
6-9-1999	Y. Sudhakar SINP, Calcutta	Study of Colossal Magnetoresistance Using Small Polaron Picture with Finite Band Width Effects
6-9-1999	B. Meenakshi IMSc	Model Checking LTL Using Net Unfoldings
7-9-1999	Rashmi Ray City College, New York	Quantum Hall Ferromagnets and Topological Excitations
8-9-1999	Prakash Mathews IMSc	Probing Large Extra Dimensions at High-Energy Colliders
9-9-1999	S. Kesavan IMSc	Isoperimetric Inequalities in PDE
14-9-1999	H. Narayanan IIT Bombay	The Principal Lattice of Partitions of a Submodular Function
15-9-1999	Asmita Mukherjee SINP, Calcutta	Twist - Four Longitudinal Structure Function: A non-relativistic Calculation in Light-Front QED
16-9-1999	V. Balakrishnan IIT, Madras	Persistence, Recurrence and Intermittency
21-9-1999	P.Sankaran CMI, Chennai	Differential Topology
22-9-1999	Nita Sinha IMSc	CP Violation and B Mesons
23-9-1999	M. Krishna IMSc	Spectral Theory of Random Self-adjoint Operators

6-10-1999	A. R. Usha Devi Bangalore University	Classical Limit of Information Theoretic Braunstien-Caves Inequalities
7-10-1999	V. S. Sunder IMSc	Fredhölm Index and Extensions of Compact Operators
7-10-1999	Kamal Lodaya IMSc	Petri Nets are not Monoids
8-10-1999	Rahul Sinha IMSc	Beauty, Can Thee Explain Why the Universe Prefers Matter?
12-10-1999	S. Uma Sankar IIT, Mumbai	Probing the Effect of Matter Term in Neutrino Long-Baseline Experiments
20-10-1999	G. Rajasekaran IMSc	Lepton-Photon Symposium (1999)—Some Highlights
20-10-1999	V. Arvind IMSc	Resolution Proofs
21-10-1999	D. S. Nagaraj IMSc	Quadratic Forms Over Rational Numbers
21-10-1999	V. Arvind IMSc	Resolution Proofs
22-10-1999	N. D. Hari Dass IMSc	Quantum Theory of the Brain: Fact or Fantasy ?
25-10-1999	V. Arvind IMSc	Lengths of Resolution Proofs
10-11-1999	V. V. Sreedhar Dublin Institute for Advanced Studies, Dublin	Duality in Quantum Liouville Theory
10-11-1999	R. J. Ranjit Daniels B. R. Barwale Chair in Biodiversity, MSSRF	In a Rapidly Developing World, Does Life Around Us Matter ?
11-11-1999	N. D. Hari Dass, Romesh Kaul IMSc	Chirality and Higgs Problems

11-11-1999	G. Rajasekaran, H. S. Sharatchandra IMSc	Renormalisation: Historical and Modern Perspectives
12-11-1999	S. Srinivasa Rao IMSc	Static Dictionaries Supporting Rank
17-11-1999	A. K. Mishra IMSc	The 1999 Nobel Prize in Chemistry: How Atoms in a Molecule Move During a Chemical Reaction
18-11-1999	Samuel S. Okoya Obafemi Awolowo Univ., Nigeria	Blow-up in Reaction-Diffusion Systems
18-11-1999	Venkatesh Raman IMSc	Exact Algorithms for MaxSat
18-11-1999	V. Arvind IMSc	Nondeterministic Instance Complexity And Hard-to-Prove Tautologies
18-11-1999	Meena Mahajan IMSc	The Complexity of Planarity Testing
19-11-1999	Anirban Pathak Visawa Bharathi University	Higher Order Solution of a Quantum Quartic Oscillator in Heisenberg Picture
25-11-1999	T. Bohr Niels Bohr Institute, Copenhagen	Spatio-Temporal Intermittency
26-11-1999	R. Thangadurai IMSc	A Lattice Point Problem
1-12-1999	J. Saint Jean Paulin University of Metz, France	Introduction to Exact Controllability and Sentinels
3-12-1999	Saiful Islam Khondaker Dhaka Univ.	Two Dimensional Variable Range Hopping in a Delta-Doped GaAs/AlGaAs Heterostructure
6-12-1999	Y. Kuramoto Tohuku University	Exact Dynamics of Orbitally Degenerate Spin Chain
7-12-1999	N. Kawakami Osaka University	Quantum Phase Transitions in Mixed Spin Systems

7-12-1999	Saiful Islam Khondaker Dhaka University	Single Electron Transport in Samples Containing *InAs* Self Assembled Quantum Dashes and Dots
9-12-1999	J. Faraut University of Paris-VI	Holomorphic Extension for Eigenfunctions
10-12-1999	V. S. Sunder IMSc	On Paragroups
13-12-1999	Mukunda P. Das Australian National Univ., Canberra	Is There a Standard Model for Low/Very Low Energy Physics?
13-12-1999	Jeeva S. Anandan University of South Carolina	Laws, Symmetries and Geometry
20-12-1999	L. Danzer Dortmund University, Germany	Geometry of Quasicrystals and Beyond
22-12-1999	S. D. Cutkosky University of Missouri-Columbia	Asymptotic Regularity and Seshadri Constants
23-12-1999	D. Suryaramana IMSc	The Circle of Ideas Around the Circle Problem
27-12-1999	N. Ramachandran Univ. of Maryland, USA	Zeta Functions of Varieties Over Finite Fields
28-12-1999	Deirdre Haskell College of the Holy Cross, Worcester Massachussets	Valued Fields and Elimination of Imaginaries
29-12-1999	C. Das IISc, Bangalore	Laser-Induced Freezing of Colloidal Systems
30-12-1999	Frank Verheest University of Ghent, Belgium	Non-Linear Wave Equations for Plasma Physics
30-12-1999	S. Banerjee TIFR, Mumbai	QCD Results from L3

30-12-1999	Walter Craig Brown University, USA	Travelling Water Waves
31-12-1999	S. Banerjee TIFR, Mumbai	Test of Standard Model from LEP Data
3-1-2000	Apoorva Patel IISc, Bangalore	Gene Coding
17-1-2000	Venkatesh Raman IMSc	Bit Probe Complexity of Set Representation
17-1-2000	Sankalpa Ghosh JNU, New Delhi	Topological Excitations in Double Layer Quantum Hall Effect at $\nu = 1$ with Spin
17-1-2000	Meena Mahajan IMSc	When Counting Helps Search
19-1-2000	Sitabhra Sinha IISc, Bangalore	Phase Transitions in the Computational Complexity of "Elementary" Cellular Automata
20-1-2000	Raghavan Rangarajan PRL, Ahmedabad	Baryogenesis in the Early Universe
20-1-2000	M. Ram Murty Queen's University, Kingston, Canada	Recent Developments in Analytic Number Theory
21-1-2000	M. Ram Murty Queen's University, Canada	Euclid, Brahmagupta and ABC
24-1-2000	J. van der Jeugt University of Ghent, Belgium	Lie (Super) Algebraic Approach to Generalised Quantum Statistics
2-2-2000	M. Pusterla University of Padova and INFN-Padova, Italy	"Quantum-like Approach in Beam Physics: Theory and Applications
2-2-2000	Sriraman Sridharan University of Perpignan, France	On Berge's Path Partition Conjecture
7-2-2000	P.K. Mohanty MRI, Allahabad	An Exactly Solvable Model of Interacting Fermions

8-2-2000	Sudipta Nandy IIT, Gauhati	Optical Soliton in Higher Order Nonlinear Schroedinger Equation
9-2-2000	Pritiraj Mohanty Caltech	Decoherence in Mesoscopic Systems
10-2-2000	Pritiraj Mohanty Caltech	In Search of Non-Newtonian Gravity or Extra Dimensions
10-2-2000	Abhishek Dhar IISc., Bangalore	Phase Transitions in Frustrated Systems
11-2-2000	Sampath Kannan University of Pennsylvania	New Models for Program Checking
15-2-2000	Radha Balakrishnan IMSc	The Schrödinger Equation as a Moving Curve
16-2-2000	G. Manoj IMSc	Spatial Correlations in Persistence
17-2-2000	Vadim Apalkov IMSc	Optical Properties of Incompressible Quantum Liquids
18-2-2000	Padmavathamma University of Mysore, Mysore	Frobenius Partition
18-2-2000	Ramesh Anishetty IMSc	A New State of Matter
23-2-2000	Haridas Banerjee SINP, Calcutta	Chiral Anomalies, Revisited
24-2-2000	Abhay Ashtekar Centre for Gravitational Physics and Geometry, Penn State	Quantum Mechanics of Geometry
25-2-2000	Abhay Ashtekar Centre for Gravitational Physics and Geometry, Penn State	Isolated Horizons and Black Hole Entropy
25-2-2000	S. D. Adhikari MRI, Allahabad.	Ramsey-type Theorems in Combinatorial Number Theory

29-2-2000	Sunil Mukhi TIFR, Mumbai	Introduction to Aspects of Branes and Antibranes
1-3-2000	Sunil Mukhi TIFR, Bombay	Brane-Antibrane Constructions
3-3-2000	Yann Bugeaud University of Pasteur, Paris	On Effective Improvements of Liouville's Inequality
3-3-2000	Supratim Sengupta IOP, Bhubaneswar	Topological Defect Formation without Phase Transitions
8-3-2000	Arul Lakshminarayan PRL, Ahmedabad	Level Dynamics in Quantum Chaos: Beyond Random Matrix Theory
10-3-2000	L. Satpathy IOP, Bhubaneswar	Nuclear Equation of States
14-3-2000	Vijay Kodiyalam IMSc	Finite Dimensional Hopf Algebras
15-3-2000	Rahul Siddharthan IISc, Bangalore	Spin-Ice Behaviour in Pyrochlores
16-3-2000	Kamales Kar SINP, Calcutta	Nuclei, Random Matrices, and Chaos
22-3-2000	Arnab Rai Choudhuri IISc., Bangalore	The Origin of Astrophysical Magnetic Fields
23-3-2000	Surajit Sengupta IGCAR, Kalpakkam	Disordering in Two Dimensions
23-3-2000	M. S. Raghunathan TIFR, Mumbai	Morphisms of Curves into Homogeneous Spaces
24-3-2000	Kapil H. Paranjape IMSc	An Introduction to Geometry
24-3-2000	Sagar Pandit PRL, Ahmedabad	Random Spread of Information on Small-World Networks
29-3-2000	A. K. Mishra IMSc	Anderson Hamiltonian for Solid Surface and Electrochemical Interface

30-3-2000	M. Krishna IMSc	Spectral Theory of Anderson Type Models
11-4-2000	K. J. Thomas Cavendish Lab., Cambridge Univ.	Ballistic Transport of Electrons in 1-d Semiconductor Devices
11-4-2000	Gurumurthy Ramanan CMI, Chennai	Linear Algebraic Methods in Combinatorics
11-4-2000	Ramesh Vishwanathan CMI, Chennai	Object Calculi
14-4-2000	R. Rajaraman JNU, New Delhi	What Makes a Theory Gauge Invariant? —An Introduction for Non-Experts
17-4-2000	R. Balasubramanian IMSc	ABC Negates the Existence of Siegel Zeros
20-4-2000	Jishnu Biswas IMSC	The Weak Lefschetz Theorem
25-4-2000	R. Jaganathan IMSc	Wavelets and Quantum Algebras
26-4-2000	A. K. Arora IGCAR, Kalpakkam	Negative Thermal Expansion in Zirconium Tungstate: Insight Through High Pressure Raman Spectroscopy
27-4-2000	Joseph Samuel RRI, Bangalore	A Critique of Barbero's Hamiltonian Formulation of General Relativity
10-5-2000	Sumati Surya TIFR	The Moduli Space of Brane Configurations
15-5-2000	K. R. Parthasarathy ISI, New Delhi	An Invitation to Quantum Error-correcting Codes
19-5-2000	V. Ravindran MRI, Allahabad	Top Quark Production in Polarised e^+ e^- Colliders

29-5-2000	Jaydeb Chakrabarti S. N. Bose Inst., Calcutta	Pattern in Chemically Active Liquids
30-5-2000	Raman Sundram Stanford University	Extra Dimensions, the Hierarchy Problem, and Graviton Resonances at Colliders
31-5-2000	Guruprasad Kar ISI, Calcutta	Quantum Inseparability: Is there any Nonlocality?
1-6-2000	Raman Sundram Stanford Univ.	Warped Compactifications and the Hierarchy Problem
5-6-2000	Raman Sundram Stanford Univ.	Anomaly-Mediated Supersymmetry Breaking
6-6-2000	P. P. Divakaran IMSc-CMI, Chennai	Quantum Symmetries of Space-Time and Gauge Interactions I
7-6-2000	Soumitro Banerjee IIT, Kharagpur	Bifurcations in Piecewise Smooth Maps and Robust Chaos
8-6-2000	Siva Athreya British Columbia Univ, Canada	On a Singular Semilinear Elliptic Boundary Value Problem and the Boundary Harnack Principle.
9-6-2000	P. P. Divakaran IMSc-CMI, Chennai	Quantum Symmetries of Space-Time and Gauge Interactions II
12-6-2000	P. P. Divakaran IMSc-CMI, Chennai	Quantum Symmetries of Space-Time and Gauge Interactions III
14-6-2000	P. P. Divakaran IMSc-CMI, Chennai	Quantum Symmetries of Space-Time and Gauge Interactions IV
15-6-2000	S. M. Hegde REC, Suratkal	Graph Labellings
22-6-2000	G. V. R. Babu Andhra University, Visakhapatnam	Existence of Fixed Points by Altering Distances and Approximation of Fixed Points
28-6-2000	Tapobrata Sarkar TIFR, Mumbai	Coputation of D brane Gauge Theories From Toric Singularities

29-6-2000	A. P. Balachandran Syracuse University	Enquiries about the Nature of Space-Time
3-7-2000	V. Srinivas TIFR, Mumbai	Zero Cycles on Normal Surfaces
10-7-2000	Arvind Nair TIFR, Mumbai	Cohomology of S-arithmetic Groups
10-7-2000	Jaikumar Radhakrishnan TIFR, Mumbai	Graph Entropy
11-7-2000	Jaikumar Radhakrishnan TIFR, Mumbai	Graph Entropy
11-7-2000	B. Meenakshi IMSc	Message Sequence Charts
12-7-2000	Jaikumar Radhakrishnan TIFR, Mumbai	Graph Entropy
13-7-2000	Bharath Sethuraman California State Universtiy, Northridge, U.S.A.	Commuting Pairs and Triples of Matrices and Related Varieties
13-7-2000	Madhav Nori University of Chicago, U.S.A.	The Motivic Fundamental Group
17-7-2000	S. V. Bhat IISc, Bangalore	Fascinating Phase Diagrams of HTSC: Insights from Non-Resonant Microwave Response Studies

2.6 Student Programmes

2.6.1 Institute JRFs

Students who **received** their Ph.D. degree during 1999-2000:

Physics

Name: **Saurya Das**
Thesis Title: Aspects of Gravitational Scattering at Planckian Energies
Thesis Advisor: P. Majumdar
University: Anna University

Name: **Radhika Vathsan**
Thesis Title: Studies in Quantization: Methods for Constrained Systems and Semi-classical Spectra of Many-body Systems
Thesis Advisor: G. Date
University: Madras University

Students who **submitted** their Ph.D. thesis during 1999-2000:

Mathematics

Name: **M. Rajesh**
Thesis Title: Some Problems in Homogenization
Thesis Advisor: S. Kesavan
University: Indian Statistical Institute

Name: **D. Surya Ramana**
Thesis Title : Some Topics in Analytic Number Theory
Thesis Advisor: R. Balasubramanian
University: Madras University

Physics

Name: **Arundhati Dasgupta**
Thesis Title: Aspects of Black Hole Thermodynamics
Thesis Advisor: P. Majumdar
University: Madras University

Name: **Pushan Majumdar**
Thesis Title: Duality Transformations of Non-Abelian Gauge Theories
Thesis Advisor: H. S. Sharatchandra
University: Madras University

Name: **Tapobrata Sarkar**
Thesis Title: Aspects of D-branes and Quantum Gravity
Thesis Advisor: T. Jayaraman
University: Madras University

Name: **Subhashis Sinha**
Thesis Title: Confined Quantum Systems: A Study of Ground State and Collective excitations
Thesis Advisor: M. V. N. Murthy
University: Madras University

The following **lecture courses** were offered during this year:

Mathematics

Course Title	Period	Lecturer
TQFTs from Subfactors	Jul-Sep 1999	V. S. Sunder
Hopf Algebras	Jan-Apr 2000	V. Kodiyalam

Physics

Classical Mechanics	Aug-Dec 1999	G. Date
Classical Electrodynamics	Aug-Dec 1999	P. Majumdar
Quantum Mechanics	Aug-Dec 1999	B. Sathiapalan
Mathematical Methods	Aug-Dec 1999	R. Jagannathan
Advanced Quantum Field Theory	Aug-Dec 1999	T. R. Govindarajan & N. D. Hari Dass
General Relativity	Aug-Dec 1999	R. Parthasarathy
Quantum Field Theory	Jan-May 2000	R. Kaul
Statistical Mechanics	Jan-May 2000	R. Shankar
Int. Cond. Matter Physics	Jan-May 2000	T. Chakraborty
Int. Particle Physics	Jan-May 2000	D. Indumathi

In addition the second year Ph.D. students in Mathematics took a reading course with V. S. Sunder and V. Kodiyalam during the year.

K. H. Paranjape gave a course entitled *Analysis I* for the students of the National Undergraduate Programme at the Chennai Mathematical Institute during the semester August - December 1999.

S. Kesavan gave a course entitled *Calculus II* for the students of the National Undergraduate Programme at the Chennai Mathematical Institute during the semester January - April, 2000.

M. Krishna gave a course entitled *Analysis II* for the students of the National Undergraduate Programme at the Chennai Mathematical Institute during the semester January - April, 2000.

2.6.2 Summer Students

Every summer, a small number of students from various institutes/universities come to our Institute and work on some learning/research projects with some faculty member for a period of four to six weeks. The following students visited the Institute during the period May - July, 2000.

Student	**Faculty**
Mathematics	
T. V. Selvakumaran	V. S. Sunder
K. Sooraj	D. S. Nagaraj
Physics	
Mary B. Rita	N. D. Hari Dass
S. P. Chockalingam	G. Menon
P. Mini Kurian	D. Indumathi
M. Lalitha	G. Date
Karthik H. Shankar	R. Anishetty
Kuver Sinha	T. Jayaraman
S. Swaminathan	R. Simon
Theoretical Computer Science	
D. R. Nikhil	V. Arvind
M. S. Srikanth	R. Ramanujam

In addition, K. Srinivasa Rao guided the M.Sc. project work of R. Gnana Guru and R. Joseph Wesley Daniels of Loyola College, Chennai.

2.6.3 Apalat Fellowship

In order to encourage bright students to take up Mathematics or Physics for their higher studies, the Institute is offering two Fellowships, one in Mathematics and the other in Physics, for students studying in and around Chennai. This goes under the name of APALAT-IMSc Scholarship. The scholarship amount is Rs. 1000 per month for 10 months of the academic year and is paid during their M. Sc. programme. Each student is expected to work under the guidance of a faculty member of the respective discipline of the Institute.

Heads of departments of Mathematics and Physics of various city colleges are contacted to suggest five bright final year B.Sc. students who are likely to join the M.Sc. programme in an institution in Chennai. Out of these, one student in each subject is selected for the award of the scholarship through a written test and/or interview. The awardees are encouraged to attend the Institute seminars and to spend their summer vacation at the Institute working under the supervision of a faculty member. On evaluation, if their progress is found satisfactory, their scholarship is extended to cover the second year of their M. Sc. programme.

2.7 Institute Associateships

The Institute has established short term Associateships in **Mathematics, Theoretical Computer Science** and **Theoretical Physics** to enable teachers from colleges and universities to visit and work at the Institute. The program is envisaged to develop interaction between the members of the faculty of the Institute and scientists in the university system. Under this program, an Associate can visit the Institute once or twice a year, up to a total of 90 days per year, each visit lasting a minimum of three weeks. The tenure of an Associate will be for a period of three years and (s)he is expected to visit the Institute at least twice during this period.

The Institute will bear the expenses of round-trip travel (by rail) from the Associate's normal place of work to Chennai and will also pay a daily allowance to cover local expenses at Chennai. During their stay at Chennai, Associates will be accommodated at the Institute Guest House.

For the year 1999-2000, the following scientists were offered Associateships.

- Dr. M. Sivakumar, School of Physics, University of Hyderabad, Hyderabad.
- Dr. A.R. Usha Devi, Department of Physics, Bangalore University, Bangalore.
- Dr. G.P. Malik, Theory Group, School of Environmental Sciences, JNU, New Delhi.
- Dr. G. Gangadhar Reddy, Department of Physics, Kakatiya University, Warangal.
- Dr. Juliet A.P. Britto, Department of Mathematics, Mangalore University, Mangalagangotri.
- Dr. S.K. Basu, Department of Computer Sciences, Banaras Hindu University, Varanasi.

In addition, Dr. V. C. Kuriokose from the Department of Physics, Cochin University of Science and Technology, Cochin, who is already an Associate of IUCAA, Pune, has been invited to visit the Institute under this program.

2.8 Visits to Other Institutions

(including participation in conferences and workshops)

Arvind, V.

Visited Ulm University, Germany from April 1 to September 26, 1999.

Visited Universitad Politecnica de Catalunya, Barcelona, Spain from December 1, 1999 to February 25, 2000. Gave a mini-course of lectures on *Hardness versus randomness.*

Visited Ulm University, Germany from March 20 to April 4, 2000 funded by a DST-DAAD project.

Balaji, K. R. S.

Visited the Abdus Salam ICTP, from June 20 to August 2,1999.

Visited The University of Wien, Vienna, Austria, for two weeks from August 3, 1999.

Balakrishnan, Radha

Presented a Seminar entitled *Curved magnetic surfaces: energy and anholonomy* at the Department of Physics, University of Pune, Pune, on September 9,1999.

Delivered an invited talk entitled *Geometrical interpretation of the time-dependent Schrödinger equation* at the conference on *Dynamical Systems: Recent Developments* held from November 4 to 6, 1999 at University of Hyderabad, Hyderabad.

Balasubramanian, R.

Visited the University of Paris VI, Paris, France, from September 15 to December 15, 1999. During the visit, gave lectures at the Universities of Nancy and Lille.

Lectured in the Monday Analytic Number Theory meet in IHS.

Delivered a lecture on *Riemann Hypothesis* in the Conference *Number Theory for Telecommunication Engineers.*

Baskaran, G.

Delivered one talk on *Physics research in India* at the Workshop on *Future Directions of Education and Research in Physics in the Asia Pacific Region* held at Singapore on August 16, 1999.

Delivered a talk on *Theory of high T_c superconductivity* at the Physics Department, National University of Singapore, Singapore, on August 17, 1999.

Delivered two invited talks at the *International Conference on Magnetic and Superconducting Materials* held at Sherief University of Science and Technology, Tehran, Iran from September 27 to 30, 1999.
i) *New Developments in the theory of superconductivity.*
ii) *Origin of spin stripes in cuprates.*

Participated in the workshop on *Quantum Magnetism* at the Institute for Theoretical Physics, University of California, Santa Barbara, California, USA from September 21 to December 13, 1999. Delivered the following two talks at the workshop:
i) *Origin of 41 meV peak in bilayer superconducting cuprates* (24 Oct 99).
ii) *Competition between charge stripes and superconductivity in cuprates* (23 Nov 99).

Visited the Department of Physics, University of California, Berkeley, California, USA and delivered a talk on *Anderson's electronic mechanism of superconductivity revisited* (16 Nov 99).

Visited the Department of Physics, Stanford University, Stanford, California, USA and delivered a talk on *Anderson's electronic mechanism of superconductivity revisited* (17 Nov 99).

Visited the Department of Theoretical Physics, Cavendish Laboratory, Cambridge University, Cambridge, UK from December 14 to 17, 1999 and delivered a talk on *Superconductivity in the Ruthenate Systems.*

Invited talk given at the Department of Atomic Energy (Solid State Physics Symposium) from December 21 to 24, 1999, at IGCAR, Kalpakkam, on *RVB theory of superconductivity - A status report.*

Delivered the 'Conference Summary Talk' at the Department of Atomic Energy (Solid State Physics Symposium) at IGCAR, Kalpakkam, on December 24, 1999.

Invited to participate in the workshop *Fifty Years of Condensed Matter Physics* honouring P.W. Anderson at Aspen, Colorado, USA, from January 10 to 14, 2000. Delivered a talk on *Anderson's solution to the theory of superconductivity and beyond.*

Invited lecturer at the SERC School on *Condensed Matter Physics and Quantum Field Theory*, at the Mehta Research Institute, Allahabad, from January 13 to 18, 2000. Delivered four talks on *Advanced topics in fractional quantized Hall effect* and one talk on *Condensed Matter Physics and Biology.*

Invited talk on *On anomalous pressure effects in high T_c superconductors* given at the *V National Conference on High Pressure Science and Technology* at Anna University, Madras, from March 1 to 3, 2000.

Delivered the Annual College Convocation Address of the Americal College, Madurai on March 25, 2000.

Delivered a talk *Physics and Biology* at the PG Department of Physics, American College, Madurai on March27, 2000.

Delivered two talks on *Stripes in Quantum Hall Systems* at the workshop on *Recent Developments in Fractional Quantized Hall Effect* held at the Radio Astronomy Center, Ooty, from April 13 to 17, 2000.

Visited the Abdus Salam International Center for Theoretical Physics, Trieste, Italy during July 1 to 31, 2000 and directed the *XII Workshop on Strongly Correlated Electron Systems.*

Basu, R.

Delivered talk on *Higher twist effects from the slope of* F_2 at the *XXIX International Symposium of Multiparticle Dynamics (ISMD99) - QCD and Multiparticle Dynamics*, Brown University in August 1999.

Visited the Nuclear Theory Group at Brookhaven National Laboratory from August 15 to September 15, 1999.

Visited the Tata Institute of Fundamental Research for Microworkshop in QGP in March 2000.

Visited EHEP group of TIFR for one week in May, 2000.

Visited The Institute for Theoretical Physics, SUNY at Stony Brook, New York from June 6 to 20, 2000 and delivered a talk on *Thrust in* e^+e^- *annihilation - then and now.*

Visited Abdus Salam International Centre for Theoretical Physics, Trieste, Italy, from June 21 to July 21, 2000.

Date, G.

Participated in the *International Conference on Gravitation and Cosmology, ICGC-2000*, held at IIT-Kharagpur from January 4 to 9, 2000. Gave a talk on *Trapping and isolated horizons: a comparison* in a workshop session.

Visited the Raman Research Institute from May 12 to 17, 2000. Gave a seminar on *Isolated horizons: an overview* .

Govindarajan, T. R.

Delivered an invited talk in *Frontiers of Fundamental Physics* at B. M. Birla Science center, Hyderabad, from December 17 to 22, 1999.

Attended *Millenium String Workshop* at JNCAR, Bangalore, from January 3 to 8, 2000.

Delivered an invited talk in *QFT-2000* at SINP, Calcutta, from Jan 17 to 23, 2000.

Indumathi, D.

Invited talk given at the DAE Symposium on *High Energy Physics*, Chandigarh, December 1999.

Jagannathan. R.

Lectured on *Quantum Aspects of Beam Physics* in the *Fourth School on the Physics of Beams* held at the Centre for Advanced Technology, Indore, during December 1999 - January 2000.

Delivered a course of lectures on *An introduction to q-series* in the DST-sponsored *Second SERC Summer School on Special Functions and Functions of Matrix Argument* organized by the Centre for Mathematical Sciences, Trivandrum, in June 2000.

Kesavan, S.

Delivered an invited talk at the *69th Annual session of the National Academy of Sciences*, held at the Barkatullah University, Bhopal, November, 1999.

Delivered a series of 5 lectures on *Isoperimetric Inequalities* at the Department of Mathematics, Calicut University, November, 1999 under the *P. Kesava Menon Endowment Lecture Series*.

Delivered a series of 5 lectures on *Homogenization* at the I.I.T., Guwahati, December, 1999, under the *Turn of the Millennium Lecture Series*.

Delivered an invited talk at the *International Workshop on Fluid Mechanics, FLUMEC 2000*, at the I.I.T., Madras, January, 2000.

Delivered an invited talk at the *National Seminar on Applications of Mathematics*, St. Joseph's College, Tiruchirappalli, February, 2000.

Delivered an invited talk at the *National Seminar on Recent Developments in Applied Mathematics*, Bharathiar University, Coimbatore, February, 2000.

Kodiyalam, V.

Delivered a course of lectures for the MTTS program held at IIT, Chennai from May 15 to June 10, 2000, on *Number Theory and Combinatorics*.

Krishna, M.

Attended *International Instructional Workshop on Wavelets and Applications*, University of Delhi from August 16 to 21, 1999.

Taught a course in the MTTS programme held at IIT, Chennai during the period May 15 to 27, 2000.

Lodaya, K.

Attended the *Workshop on Data Structures*, held at IIT Chennai, during December 11-12, 1999.

Attended the *19th FSTTCS Conference*, held at IIT Chennai, from December 13 to 15, 1999.

Attended the *Workshop on Mobile Computing*, held at IMSc, during December 16-17, 1999.

Madhusudan, P.

Visited INFORMATIK VII, RWTH-Aachen, Aachen, Germany from November, 1999 to August, 2000.

Attended *STACS 2000 (Annual Symposium on Theoretical Aspects of Computer Science)*, held at Lille, France from February 17 to 19, 2000.

Attended *PROCOPE Project, First Workshop: Graphs and Transition Systems: Specification Methods and Applications*, Bordeaux, France, from May 4 to 6, 2000.

Mahajan, Meena

Visited the Department of Mathematics and Computer Science at Loyola University, Chicago, U.S.A. from September 8 to 10, 1999. Delivered a talk on *Determinant: combinatorics, algorithm, complexity.*

Attended the *Workshop on Data Structures and Algorithms* at the Indian Institute of Technology, Madras, during December 11-12, 1999.

Attended the *Nineteenth Foundations of Software Technology and Theoretical Computer Science (FST&TCS) Conference* at Chennai from December 13 to 15, 1999.

Attended the *Tenth International Symposium on Algorithms and Computation (ISAAC)* at Chennai from December 16 to 18, 1999.

Attended the *Workshop on Approximation Algorithms* at the Indian Institute of Technology, Madras, during December 19-20, 1999.

Visited the Department of Computer Science at the Humboldt University, Berlin, Germany, from January 22 to February 5, 2000, under the DST-DAAD Personnel Exchange Scheme.

Visited the Department of Computer Science at the University of Aarhus, Denmark, from February 6 to 16, 2000. Delivered a talk on *An NC algorithm for finding a perfect matching in bipartite planar and small genus graphs* on February 7, 2000 and one on *A combinatorial algorithm for Pfaffians* on February 11, 2000.

Attended the *17th International Symposium on Theoretical Aspects of Computer Science (STACS 2000)* at Lille, France, from February 17 to 19, 2000. Presented the paper *The*

complexity of planarity testing.

Visited the Department of Computer Science and Engineering at the Indian Institute of Technology, Bombay, from March 8 to April 24, 2000 and on July 14, 2000. Delivered a talk on *An NC-algorithm for finding a perfect matching in bipartite planar and small genus graphs* on July 14, 2000.

Attended the Workshop on *Mathematical Methods in Computer Science* held at the Department of Computer Science and Automation at the Indian Institute of Science, Bangalore from July 24 to Aug 4. Gave a talk on *Constant-depth circuits, Fourier coefficients, and learnability.*

Majumdar, P.

Presented a plenary lecture entitled *Quantum Aspects of Black Holes* at the *International Conference on Gravitation and Cosmology*, held at Kharagpur in January, 2000. Chaired a parallel session on *Quantum Black Holes* at this meeting.

Visited Cambridge University (DAMTP), Imperial College, Penn State University, Niels Bohr Institute and the Albert Einstein Institute during the period April 24 to June 28, 2000 and delivered talks.

Presented contributed papers at the *IX Marcel Grossmann Meeting* in Rome, Italy, in July 2000.

Manoj, G.

Participated in the *DAE Solid State Physics Symposium* held at IGCAR, Kalpakkam from the period December 20 to 24, 1999 and presented a poster titled *Dynamic scaling and fractal formation in persistence.*

Visited TIFR, Mumbai from February 21 to 26, 2000 and delivered a talk on *Spatial correlations in persistence.*

Visited S. N. Bose National Centre for Basic Sciences, Calcutta from February 28 - March 3, 2000.

Visited SINP, Calcutta on March 4, 2000 and delivered a talk on *Spatial correlations in persistence.*

Visited IOP, Bhubaneswar from March 6 to 9, 2000 and gave a talk on *Spatial distribution of persistent sites.*

Visited The Abdus Salam ICTP, Trieste, Italy from May 5 to 28, 2000 and delivered a talk on *Persistence in nonequilibrium systems: spatial correlations.*

Visited Universitè Paul Sabatier, Toulose, France from May 29 to 31,2000 and delivered a talk on *Spatial distribution of persistent sites.*

Visited The University of Manchester, Manchester, U.K from June 1 to 4, 2000.

Meenakshi, B.

Attended the *19th International Conference on Foundations of Software Technology and Theoretical Computer Science (FST & TCS)* at Chennai from December 13 to 15, 1999.

Menon, G. I.

Attended and delivered a talk at the *Workshop on Dynamics of Non-Equilibrium Systems*, ICTP, Trieste, Italy in August, 1999.

Visited the Institut Curie (Paris, France) for 10 days in August-September, 1999 and delivered a seminar.

Delivered a seminar at the AMOLF/FOM Institute (Amsterdam) in September, 1999.

Delivered two seminars at the LUC (Hasselt, Belgium) in September, 1999.

Delivered a colloquium talk at the University of Paris, Orsay in September, 1999.

Delivered Seminar at TIFR (Mumbai) in September, 1999.

Invited Speaker at the *Workshop on Non-Equilibrium Systems*, Bangalore, India in November, 1999.

Visited the National Centre for Biological Sciences, Bangalore for two days in November, 1999.

Invited Speaker at the *Special Session on Superconductivity, DAE Symposium on Solid State Physics*, Kalpakkam, India in December, 1999.

Invited Lecturer on *Introduction to Biological Physics* (4 lectures) at the *L.A. Meera Fifth Frontier Meeting in Physics*, Mysore, India.(January-February, 2000).

Visiting Scientist, Department of Condensed Matter Physics and Materials Science, Tata Institute of Fundamental Research, Mumbai, from February 24 to March 7, 2000. Presented a series of 8 lectures on *Current Trends in Vortex State Physics*.

Invited Speaker at the Meeting on *Slow Dynamics and Freezing in Condensed Matter*, School of Physical Sciences, Jawaharlal Nehru University, in March, 2000.

Delivered a Special Lecture at the *Programme for Gifted Youth 2000*, IIT, Madras, in April, 2000.

Mishra, A. K.

Visited Indian Institute of Science, Bangalore from August 1 to 31, 1999. Gave a special lecture on *Chemisorption at the electrode-electrolyte interface* in the department of Inorganic

and Physical Chemistry on August 27, 1999.

Participated in the *Ninth National Convention of Electrochemists* at the Regional Engineering College, Surat, during November 26-27, 1999. Gave a talk on *Metallization effects of an adsorbed layer.*

Visited Central Electrochemical Research Institute, Karaikudi from December 15 to 21, 1999. Gave a lecture on *Femto-second spectroscopy* on December 20, 1999.

Presented a talk in the SAEST Technical Meeting on December 22, 1999, at CSIR Complex, Chennai, on *Time evolution of a chemical reaction.*

Participated in an *International Conference on Spin-Statistics Connection and Commutation Relations: Experimental Test and Theoretical Implication* held at Capri Island, Italy, from May 31 to June 3, 2000. Presented two talks, titled *Generalized Fock Spaces and New Forms of Quantum Statistics* and *Quantum Field Theory for Orthofermions and Orthobosons* in the conference.

Visited Max-Planck Institute for Physics of Complex Systems, Dresden, Germany from June 4 to July 22, 2000.

Attended, as one of the participants in a five member Indian delegation, the *IVth Indo-German Seminar on Molecular Electrochemistry*, held from July 10 to 14, 2000 at Dresden, Germany, under INSA-DFG bilateral cooperation. Presented a talk on *Modelling the Electronic structure of Atomic and Molecular Adsorbates at an Electrochemical Interface.* In connection with this conference, subsequently visited Han-Meitner-Institute, Fritz-Haber Institute and BAM in Berlin and DECHEMA in Frankfurt.

Visited the Department of Chemistry, University of Ulm, Germany during July23-24, 2000 and delivered a talk on *Theory of Adsorption on Metallic Electrodes.*

Murthy, M. V. N.

Visited Physical Research Laboratory, Ahmedabad, from October 24 to 30, 1999. Delivered one colloquium on *Neutrinos from stellar collapse* and a seminar on the *Geometry of two dimensional clusters.*

Visited The Institute for Theoretical Physics, University of Regensburg, Germany, from April 27 to May 4, 2000. Delivered a seminar on the *Neutrinos from stellar collapse: effect of neutrino oscillations.*

Visited The Department of Physics and Astronomy, McMaster University, Canada from May 5 to July 8, 2000.

Nagaraj, D. S.

Visited the Mehta Research Institute from December 22, 1999 to January 17, 2000. Gave a lecture on *Generalized Bernoulli numbers.*

Delivered a course of 24 lectures and problem sessions on *Algebra* at the MTTS programme conducted by NBHM at RIE, Mysore, from May 22 to June 17, 2000.

Paranjape, K. H.

Delivered a talk on *A new kind of invariant for cycles* at the TIFR on August 2, 1999.

Delivered a talk on *Homological versus algebraic equivalence on threefolds with trivial canonical bundle* at the University of Chicago, Illinois, USA on December 1, 1999.

Delivered a talk on *Computers and communication for mathematics: the Indian context* during the MSRI conference on *The Future of Mathematical Communication*, held at MSRI, Berkeley, California, USA, from December 2 to 6, 1999.

Delivered a talk on *A counter example to a conjecture of Green* at the Department of Mathematics, UCLA, Los Angeles, California, USA on December 11, 1999.

Delivered a talk on *Some examples related with Bloch's conjecture* during the International Colloquium on *Algebra, Arithmetic, Geometry*, held from January 3 to 14, 2000, at the TIFR, Mumbai, India.

Delivered a talk on *Differential equations arising in Algebraic Geometry* during the Ramanujan Symposium, held from January 13 to 16, 2000 at the Ramanujan Institute, Chennai, India.

Delivered a talk on *Sections of Jacobian Fibrations* during the conference following the workshop on *Vanishing Theorems and Effective Results in Algebraic Gemetry* held from April 24 to May 13, 2000 at the ICTP, Trieste, Italy.

Delivered a talk on *The Hodge conjecture for a general Prym variety* at the ICTP, Trieste, Italy on June 13, 2000.

Parthasarathy, R.

Participated in the *Workshop on Small Accelerator for Universities for Basic and Applied Sciences*, at the Department of Nuclear Physics, University of Madras, during October 25-26, 1999 and gave an invited talk on *Low Energy Nuclear Reactions using Accelerators.*

Delivered the Valedictory Address of the DST sponsored *IV SERC School on Nuclear Physics, Hadron Physics and Quark-Gluon Plasma*, at the Department of Nuclear Physics, University of Madras, on *Time Asymmetry*, on December 4, 1999.

Participated in the *Quantum Field Theory Workshop*, held at the Saha Institute of Nuclear Physics, Calcutta, from January 18 to 22, 2000 and gave an invited talk on *Confining Configurations in QCD.*

Visited KEK, Tokyo from March 1 to 6, 2000 and gave a seminar talk.

Participated in the *International Conference on CONFINEMENT 2000*, at Osaka University, RCNP, Osaka, Japan from March 7 to 10, 2000, as an Invited Plenary Speaker and gave an invited talk on *Confining Configurations in QCD*.

Visited the Yukawa Institute for Theoretical Physics, Kyoto from March 11 to 18, 2000 and gave seminar on *Infrared Region of QCD and Confinement*.

Rajasekaran, G.

Attended the *XIX International Symposium on Lepton and Photon Interactions at High Energies*, Stanford University, USA, from August 9 to 14, 1999.

Visited North Eastern Hill University, Shillong from October 25 to 30, 1999 and gave two talks on *Neutrino Physics*.

Visited Saha Institute of Nuclear Physics, Calcutta from October 31 to November 2, 1999 and gave a colloquium on *Neutrino Oscillations*.

Gave six lectures on *Elementary Quantum Field Theory* at the *SERC School on Nuclear Physics (Hadrons and QGP)* at University of Madras during November 15 - 20, 1999.

Gave a lecture entitled *From Quantum Mechanics to Quantum Field Theory* at the IPA Symposium *A harvest of Nobels* held at IIT, Madras on November 22, 1999.

Gave a seminar on the *Construction of the gauge theory of the electroweak and strong interactions* at Raman Research Institute, Bangalore on November 24, 1999.

Gave a lecture *A brief history of high energy physics leading upto the Standard Model*, at the *SERC School on Beam Physics* at CAT, Indore on December 29, 1999.

Attended the *6th Workshop on High Energy Physics Phenomenology* held at IMSc, Madras from January 3 to 15, 2000, gave an invited talk on *Phenomenology of neutrino oscillations* and participated in the working group activity on *Neutrinos and Astroparticle Physics*.

Attended the *Workshop on Quantum Field Theory* held at SINP, Calcutta, from January 17 to 23, 2000 and gave an invited talk on *Electroweak Theory without Higgs*.

Gave a lecture *Physics at the Turn of the Century* at Mehta Research Institute, Allahabad on February 1, 2000.

Visited Mc Master University, Hamilton, Canada, and participated in the Symposium on *From Nuclei to Bose Condenstates* on May 6, 2000. Gave a seminar talk on *Neutrinos from Supernovae* on May 7, 2000.

Visited University of California, Riverside, USA from April 24 to July 11, 2000. Gave seminars on *Neutrinos from Supernovae* and on *Dynamical breaking of electroweak symmetry*.

Rajesh, M.

Attended the workshop on *Modelling Real Systems* held at ICTP, Trieste between September 27 and October 22, 1999.

Delivered a lecture on *H-convergence for systems* at the Department of Mathematics, Indian Institute of Science, Bangalore on May 11, 2000.

Ramachandran, R.

Participated in the Indian Academy of Sciences Annual Meeting at Lucknow, from October 29 to November 1, 1999.

Visited IIT Kanpur from November 1 to 3, 1999. Gave an informal seminar on *Evolution of Dualities in Strings* on November 2, 1999.

Participated in the 9th Session of Indo-Russian Joint Council for ILTP, at New Delhi, during December 6-7, 1999.

Participated and inaugurated the *Workshop on High Energy Physics Phenomenology (WHEPP6)* at IMSc, Chennai, from January 3 to 15, 2000.

Visited IUCAA, Pune, from April 22 to 30, 2000. Delivered a colloquium on *Dualities in String Theories* on April 27, 2000.

Raman, V.

Gave a talk on *Some results on tournaments* at Barathidasan University, Tiruchi on November 20, 1999.

Attended the Pre (FST& TCS) Conference *Workshop on Data Structures*, Chennai during December 11-12, 1999.

Attended the *19th International Conference on Foundations of Software Technology and Theoretical Computer Science (FST & TCS)* at Chennai from December 13 to 15, 1999.

Attended the *10th International Symposium on Algorithms and Computation (ISAAC)*, Chennai from December 16 to 18, 2000, and presented a contributed paper.

Gave a set of lectures on *Graph Algorithms* in the UGC refresher course at Pondicherry University during February 25-26 2000.

Gave a talk on *Feasible Computation and NP-completeness* at the *Ramanujan Memorial Talk* at Annamalai University on March 8, 2000.

Visited the Humboldt University, Berlin, from April 28 to May 3, 2000.

Visited the University of Waterloo, Canada from May 4 to June 19, 2000. Gave a talk on *Parameterized Complexity of Finding Subgraphs with Hereditary Properties.*

Visited the University of Western Ontario, Canada, on May 19, 2000, and gave a talk on *Parameterized Complexity of Finding Subgraphs with Hereditary Properties*.

Visited the Victoria University of Wellington, New Zealand, from July 19 to 25, 2000.

Attended the *Sixth Annual International Conference on Computing and Combinatorics (COCOON 2000)*, during July 26-27, 2000, at Sydney, Australia, and presented a contributed paper.

Attended the workshop on *Mathematical Methods in Computer Science* at IISc, Bangalore from July 31 to August 3, 2000.

Ramanujam, R.

Visited the Institut für Informatik, Technische Universität München, Germany, from May 1 to July 23, 2000.

Gave a course of 25 lectures at Technische Universität München from May 3 to July 21, 2000, on *Temporal logic and distribuuted systems*.

Gave a talk at RWTH, Aachen, Germany, on June 26, 2000, on *Message passing in finite state environments*.

Participated in the conference on *Logic and Formal Theory of Decisions*, from June 30 to July 2, 2000, Torino, Italy.

Gave a talk at Universita di Pisa, Italy, on July 4, 2000, on *Local reasoning about knowledge in distributed systems*.

Gave a talk at Graduetenkolleg für Informatik und Mathematik, Ludwig Maximilian Universität, München, Germany, on July 7, 2000, on *Reasoning about security in logics of knowledge and belief*.

Participated in the *Workshop on Theoretical Aspects of System Security* on July 8 and 9, 2000, Geneva, Switzerland.

Presented the paper on *Reasoning about message passing in finite state environments* at the *International Colloquium on Automata, Languages and Programming*, from July 10 to 15, 2000, Geneva, Switzerland.

Presented the paper on *An automaton model of user-controlled navigation on the web* at the *Conference on Implementation and Applications of Automata*, from July 24 to 26, 2000, University of Western Ontario, London, Canada.

Sabu, N.

Attended the workshop on *Elastic Shells: Modelling, Analysis and Numerics* held at the MSRI, Berkeley, USA, from April 17 to 28, 2000.

Sankararaman, Sumithra

Attended a discussion meeting on *Soft Condensed Matter Physics* at Dhvanyaloka, Mysore from January 27 to February 2, 2000.

Attended the *SERC School on Field Theories in Condensed Matter Systems* between February 13 and March 4, 2000 at MRI, Allahabad and gave an informal talk on *Shape deformations in skyrmion lattices near the $\nu = 1$ quantum Hall ground state.*

Attended a workshop on *Recent Trends in Quantum Hall Effect* at Ooty, between April 17 and 21, 2000 and gave a talk on *Shape deformations in skyrmion lattices near the $\nu = 1$ quantum Hall ground state.*

Sathiapalan, B.

Visited MRI in October 1999 to attend the *String Workshop.* Gave a colloquium entitled *Chaos, Black Holes and Gauge Theories.*

Attended the *Millenium Workshop in String Theory* organized at the JNCentre, Bangalore. from Jan 4 to 11, 2000. Gave a talk entitled *Loop Variables.*

Visited University of Technology, Isfahan, Iran, to give some lectures in string theory at the *Isfahan String School*, held from May 1 to 14, 2000. Also gave a talk on *Loop Variables* at the Workshop organized after the school.

Simon, R.

Participated in the *National Laser Symposium* held at the University of Hyderabad, from December 15 to 17, 1999 and gave an invited talk on *Quantum Information.*

Participated in the *Winter Institute on Foundations of Quantum Theory and Quantum Optics* held at S.N. Bose National Centre for Basic Sciences, Calcutta, from January 1 to 13, 2000 and gave an invited talk on *Positive Maps which are not Completely Positive: Application to Quantum Inseparability.*

Sinha, R.

Visited Academia Sinica, Taiwan, from November 24 to December 8, 1999.

Delivered an invited talk at the *The Third International Conference on B physics and CP violation,* held in Taiwan from December 3 to 7, 1999.

Visited Nagoya University, Nagoya, Japan, from December 8 to 15, 1999.

Delivered an invited talk at *WHEPP-6: WorkShop in High Energy Physics Phenomenology*, IMSc, Madras, January 3 to 15, 2000.

Delivered a summary talk of the activity of the B Physics and Collider Physics working groups, at *WHEPP-6: WorkShop in High Energy Physics Phenomenology*, IMSc, Madras, January 3 to 15, 2000.

Visited Université de Montréal, Montréal, Canada, during May-June 2000.

Sridhar, R.

Delivered a series of lectures on *Elecromagnetic Theory* to the post graduate students at the Department of Nuclear Physics of the University of Madras from January to May,2000.

Delivered a series of four lectures on *New Methods to Solve Differential Equations* at the UGC Staff College, Bharathiar University, Coimbatore during July 28-29, 2000.

Srinivas, K.

Delivered 5 talks on *Dirichlet theorem for primes in arithmetic progression and Dirichlet class number formula*, at an instructional conference on *Algebraic Number Theory* held at Central University, Hyderabad from December 13 to 18, 1999.

Delivered Inaugural talk at IIT Madras in *FORAYS-2000* on February 19, 2000 on *On the Golden Theorem of Gauss.*

Delivered 3 talks on *Cryptography and Number theory* at a *Workshop on Cryptography and Data Security*, organised by AU-KBC center for Internet & Telcom Technologies, Anna University (M.I.T Campus) from June 21 to 24, 2000.

Srinivasa Rao, K.

Participated in the *International Symposium on Quantum Theory and Symmetries*, organized by the Arnold Sommerfeld Institute for Mathematical Physics of the Technical University of Clausthal, at Goslar, Germany, from July 18 to 22, 1999 and delivered an invited talk on the *Symmetries of the 9-j coefficient and summation and transformation formulas for hypergeometric series.*

Visited the Department of Mathematics, University of Vienna, Austria, for one week, from July 23 to 31, 1999.

Participated in the International Symposium *Symmetries in Science XII*, held at the Collegium Mehrerau in Bregenz, Austria, from August 1 to 6, 1999 and delivered an invited talk on *Symmetries in Quantum Theory of Angular Momentum*, and also chaired a session.

Visited the Institute for Theoretical Nuclear Physics, of the University of Bonn, Bonn, Germany from August 7 to 20 and the Arnold Sommerfeld Institute for Mathematical Physics, Technical University of Clausthal, Germany from September 4 to 30, 1999, as an Alexander von Humboldt Foundation Fellow.

Visited the Department of Applied Mathematics and Computer Science, University of Ghent, Belgium from August 21 to September 3, 1999 and during this period delivered a lecture on

Quantum Computing.

Visited the University of Paris, France, and delivered a lecture on the work of Srinivasa Ramanujan, on October 4, 1999, and visited the "Pi- Room" in Paris, France.

Visited the Department of Mathematics, University of Nice, Nice, France from October 6 to 12, 1999 and delivered a lecture on the life and work of Srinivasa Ramanujan during this period.

Invited to present the project *CDs on Ramanujan* at the Project Advisory Committee meeting of the Department of Science and Technology, held during November 2 - 3, 1999, at the University of Pune – a project of the Institute of Mathematical Sciences, Madras and the National Multimedia Research Center of C-DAC, Pune. During this period, gave a special lecture on Ramanujan's life and work in the *Refresher Course in Linear Algebra*, conducted by the Department of Mathematics, on November 2, 1999. Also gave a lecture on *Selected topics in Quantum Theory of Angular Momentum*, at the Department of Physics of the University of Pune, on November 3, 1999.

Visiting Professor, Indian Institute for Advanced Study, Shimla, from November 16 to 30, 1999. During this period a series of three lectures were delivered, entitled *Srinivasa Ramanujan, the mathemagician of the millennium.* Also delivered a lecture on the work of Ramanujan at the Mathematics Department of the Himachal Pradesh University, during this period. (ref.: arXiv.org, math.HO/0003184).

Invited to give two lectures on the life and work of Srinivasa Ramanujan, at the Central Leather Research Institute, Chennai, on December 22, 1999, on the occasion of the 112th Birth Anniversary of Ramanujan.

Invited to speak on the *Relevance of Ramanujan today* and project the Pilot CD of the author on Ramanujan, at the I.I.T., Madras, on the *Ramanujan Day Symposium*, on December 22, 1999.

Invited to inaugurate *Euphoria 2000* and deliver a lecture on *Mathematical Modeling*, at the MOP Vaishnav College, Chennai, on January 20, 2000.

Invited to lecture on *Careers in Mathematical Sciences*, as a part of the Career Counselling programme for Plus 2 students organized by the Periyar Science and Technology Center, Chennai, at the Hindu Senior Secondary School, on February 24, 2000.

Participated in the *First Annual Conference of the Society for Special Functions*, held at Jodhpur, during March 2 - 3, 2000, by giving an invited talk on *Transformations of hypergeometric series* and also chairing a session.

Participated in the Conference on *Tantrasangraha - 500*, held at the Theoretical Physics Department of the University of Madras during March 11 - 12, 2000, and Chaired a session.

Invited to deliver the Key Note Address on the role of *Mathematics in Computers*, at the P.S.G. Arts College, Coimbatore, on March 21, 1999.

Part of the *Meet the Scientist* programme conducted by the Anna University for Rural talented students of the VII and IX standard schools during May 19 - 20, 2000.

Mathematics-a tool for development, in Science Talk, broadcast by the All India Radio, Chennai, on May 24, 2000.

Resource Person for lectures on *Summation and Transformation of hypergeometric series and Mathematica*, in the *Second SERC School on Special Functions and Functions of Matrix Argument*, held at Thiruvananthapuram from June 11 to 23, 2000, and gave a course of (20) lectures and computer practicals/exercises.

Participated in an *International Conference on the Works of Srinivasa Ramanujan*, at the University of Mysore during July 1 - 2, 2000 by giving an invited talk entitled: *On the hypergeometric* ${}_3F_2(1)$ *series* and by Chairing a Session.

Gave a lecture on the *Life and Work of Srinivasa Ramanujan*, at the Aeronautical Development Establishment, Defence Research & Development Organisation, Bangalore, on July 10, 2000.

Sunder, V. S.

Attended the Workshop on *Quantum Probability and Infinite-Dimensional Analysis*, held at Jawaharlal Nehru Centre, Bangalore from December 14 to 18, 1999, and lectured on *Flatness and Fusion Coefficients* .

Was one of the three principal speakers at the *Turn of the Millennium Lectures in Mathematics* organised by IIT Guwahati from December 20 to 24, 1999 and gave a course of 5 lectures on *Modules over* II_1 *factors*.

Attended the *Conference on Functional Analysis and Linear Algebra*, held at ISI, Delhi, from January 4 to 7, 2000, and lectured on *Spectra of principal graphs*.

Attended a *Discussion Meeting on Harmonic Analysis*, held at IIT, Kanpur, from January 9 to 12, 2000, and lectured on *Spectra of principal graphs*.

Delivered the *11th Ramanujan Endowment Lecture* at the Mathematics Department, Anna University on Januray 19, 2000; the title of the lecture was *On Majorisation*.

Gave a lecture on *Discrete series of discrete groups*, at the *Seventh Ramanujan Symposium on Potential Theory and Function Theory* at the Ramanujan Institute, Madras, on January 20, 2000.

Gave a lecture on *Standard graph invariants of subfactors* at the University of Hyderabad on March 9, 2000.

Visited the University of New South Wales at Sydney, Australia for a month in May, 2000; delivered lectures on *Principal graphs of subfactors* at the Mathematics Colloquium, and on *Factor orbit equivalence and subfactors* at the Ergodic Theory Seminar.

Visited the University of Newcastle for a week in May 2000, and gave a lecture on *Flatness and fusion coefficients*.

Varadarajan, Suneeta

Presented work at a seminar in *The Millenium Meeting in String Theory*, JNCASR, Bangalore, India from January 3 to 7, 2000.

2.9 Collaborative Projects with Other Institutes

2.9.1 Indo-Russian Integrated Long Term Program of S&T

As a part of the Indo-Russian cooperation in Science and Technology during 1998, a three year proposal on *Strings, Topological and Integrable Field Theories* was proposed. The first part of the proposal resulted in a Russian-Indian International Workshop on 'Topological and Integrable Field Theories' was organized at Dubna, Russia from August 11 to 14, 1998. In the 9th Session of the Joint Council of ILTP held at New Delhi during December 6-7, 1999, the progress of the project was reviewed and the Council recommended that the project be continued. The plan for the year 2000-2001 includes 6 man months of visits of Russian Mathematicians to India, 4 - 6 man months of visits by Indians to Russia and a binational workshop to be organized by our Institute by the last week of December 2000 or 1st week of January 2001 on *Strings, Topological and Integrable Field Theories* at a suitable location in India.

2.9.2 Federation Arrangement with Abdus Salam ICTP

Federation arrangement with the Abdus Salam International Centre for Theoretical Physics, Trieste has been renewed for three years from 1999. The agreement provides for persons from our Institute, selected by us in cosultation with them, to visit ICTP for a total period of 150 days on a cost sharing basis. While ICTP will cover the local hospitality and *Lit* 4,800,000 towards the travel expenses for each person, the Institute will bear the remaining travel cost. The timing and the duration of the visit (minimum duration 3 weeks) may be so arranged to take advantage of various activities at ICTP. The agreement stipulates that the privilege is made use of for the 'junior' members of the Institution, with a age limit of 40 years.

Pushan Majumdar visited the Abdus salam ICTP between April 15 and May, 30, 2000 to continue on going research activity, at the High Energy Physics Department, in Duality, Topological Field Theory and Statistical Field Theory.

2.9.3 DST-NSF Project in Mathematical Physics

A project of collaborative research in *Spectral and Inverse Spectral Theories of Schrödinger Operators* started during June 1999 and is to last for three years. This project is funded jointly by the Department of Science and Technology in India and the National Science Foundation in the USA.

The researchers involved in the project are M. Krishna (IMSc), K. B. Sinha, (ISI, Delhi) and A. N. Mohapatra (University of Goa) on the Indian side and P. Hislop (University of Kentucky), W. Craig (Brown University) and F. Gesztesy (University of Missouri) on the US side.

As part of the project, P. Hislop and W. Craig visited the Institute during December 1999. There will be a workshop on *Spectral and Inverse Spectral Theories of Schrödinger Operators* in Goa during December 2000 and it is expected to have about 50 participants from all over the world.

2.9.4 DST-DAAD Project in Theoretical Computer Science

A collaborative research project in the area *Algorithmic/Complexity Issues in Fixed Parameter Tractability* was started in June 1999 and is to continue until June 2001. The project is funded jointly by DST (Department of Science and Technology) in India and DAAD (Deutsche Akademische Austausch Dienst) in Germany.

The researchers involved in the project are: V. Arvind, M. Mahajan, S.S. Rao, V. Raman (IMSc), K.V. Subrahmanyam (CMI) from the Indian side, and J. Köbler, W. Lindner, and J. Mayer (Humboldt University, Berlin), R. Schuler (Ulm Univerisity) from the German side.

The following research visits were made as part of the project: (i) S.S. Rao visited Ulm University during July 1999, (ii) J. Köbler and J. Mayer visited IMSc during December 1999 (iii) M. Mahajan visited Humboldt University during February 2000, (iv) V. Arvind visited Ulm University during March 2000, and (v) V. Raman visited Humboldt University during April 2000.

2.10 Other Professional Activities

Arvind, V.

Member, Programme Committee, *19th FST & TCS* conference, December, 1999.

Balakrishnan, Radha

Member, Advisory Committee for the conference on *Dynamical Systems: Recent Developments*, November, 1999, University of Hyderabad.

Balasubramanian, R.

Member, Scrutinising Committee, National Academy of Sciences, Allahabad.
Member, Editorial Board, *Indian Journal of Pure and Applied Mathematics.*
Member, Editorial Board, *National Academy of Sciences Newsletter.*
Member, Programme Advisory Committee, SNBCBS.
Member, Management Advisory Committee, DST, Government of India.
Member, Research Advisory Committee, Chennai Mathematical Institute.

Basu, R.

Convener and Member, National Organizing Committee, *Sixth Workshop in High Energy Physics Phenomenology (WHEPP-6)*, held at IMSc, Chennai, from January 3 to 15, 2000.

Govindarajan, T. R.

Vice-President, Indian Physics Association, Madras Chapter.

Jayaraman, T.

Member, Organizing Committee, *Strings 2001.*

Kalyana Rama, S.

Organiser, Journal Club talks on String Theory, Quantum Gravity, etc.

Kesavan, S.

Member, National Board for Higher Mathematics.
Member, Apex Committee, National Undergraduate Programme, Chennai Mathematical Institute.
Member, Programme Implementation Committee, National Undergraduate Programme, Chennai Mathematical Institute.
Reviewer, *Mathematical Reviews.*

Krishna, M.

Member, Project Advisory Committee for Mathematical Sciences, DST, Government of India.
Reviewer, *Mathematical Reviews.*

Lodaya, K.

Member, Programme Committee, *19th FST & TCS* Conference, December, 1999.
Member, Organizing Committee, *Workshop on Mobile Computing*, December, 1999.
Treasurer, Indian Association for Research in Computing Science, 2000.

Mishra, A. K.

Visiting Associate, Central Electrochemical Research Institute, Karaikudi.
Vice-Chairman, Electronics Group, Society of Advancement for Electrochemical Science and Technology.

Paranjape, K. H.

Associate Editor for the *Proceedings of the Indian Academy of Sciences (Mathematical Sciences).*
Member, Editorial Board for the *Journal of the Ramanujan Mathematical Society.*
Member, Editorial Board for *Resonance - A Journal of Science Education*, Indian Academy of Sciences.
Member, Committee on Electronic Information and Communication of the International Mathematical Union.

Rajasekaran, G.

Member, Local Organizing Committee, *WHEPP - 6.*
Chairman, National Advisory Committee, Symposium on *Current Developments in Theoretical Physics*, MRI, Allahabad, October 2000.
Member, Physics Sectional Committee, INSA, New Delhi.
Member, Governing Council, Mehta Research Institute, Allahabad.
Member, Bhatnagar Award Committee, CSIR, New Delhi.

Ramachandran, R.

Member, Finance Committee, S N Bose Advanced Centre for Basic Sciences, Calcutta.
Member, Board of Studies, Indira Gandhi National Open University, New Delhi.
Member, School of Physics Board, University of Hyderabad.
Member, Board of Research, University of Madras, Chennai.
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.
Vice Presidednt, MALIBNET, Madras Library Network.
Member, DST-ICTP Fellowship committee.

Raman, V.

Co-organized the Pre (FSTTCS) conference, *Workshop on Data Structures*, December, 1999.
Co-chaired the Program Committee of *FST & TCS* conference, December, 1999.

Ramanujam, R.

Co-chaired the Programme Committee of the *19th FST & TCS* conference, December, 1999.
Co-organized the Post-conference workshop on *Foundations of Mobile Computation*, December, 1999.

Simon, R.

Member, Programme Advisory Committee (PAC) on *Lasers, Optics, Atomic and Molecular Physics*, DST, Government of India.
Member, Editorial Board, *Pramana - Journal of Physics.*

Sinha, R.

Scientific secretary for the *The Third International Conference on B physics and CP violation*, held at Taiwan from December 3 to 7, 1999.
Member, National Organizing Committee, *WHEPP-6.*
Member, National Organizing Committee for XIV *DAE Symposium in High Energy Physics*, to be held at University of Hyderabad, December 2000.

Sinha, Sudeshna

Member, Advisory Editorial Board of the AIP journal *Chaos.*

Srinivas, K.

Member, Programme Implementation Committee, National Undergraduate Programme, Chennai Mathematical Institute.

Srinivasa Rao, K.

Edited the first *Newsletter* of the Society for Special Functions and their Applications.
Member, Organizing Committee, *Tantrasangraha - 500*, organized by the Department of Theoretical Physics, University of Madras, March 2000.
Member, Organizing Committee, Second SERC Summer School on *Special Functions and Functions of Matrix Argument (Theory, Applications, Real and Complex Cases*, Centre for Mathematical Sciences, Tiruvananthapuram, May - June, 2000.
Member, Advisory Board, *International Conference on Number Theory and Discrete Mathematics* in honour of S. Ramanujan, Centre for Advanced Study in Mathematics, Punjab University, October, 2000.
Editor (*Newsletter*) and Librarian for the Society for Special Functions and their Applications.

Sunder, V. S.

Member, Editorial Board for the Proceedings of the Indian Academy of Sciences (Math. Sci.).
Member, Editorial Board for *Journal of the Ramanujan Mathematical Society.*
Member, Editorial Board of the *Texts and Readings in Mathematics* (TRIM) series published by the Hindustan Book Agency.
Member, Sectional Committee for Mathematics of the Indian Academy of Sciences.
Member, Board of Studies of the School of Mathematics and Computer/ Information Sciences, University of Hyderabad.
Member, Programme Implementation Committee, National Undergraduate Programme, Chennai Mathematical Institute.

2.11 Visitors

Name	Affiliation	Period of Visit
Pari, G.	California State University, USA	1.7.99 to 30.11.99
Prakash Mathews	TIFR, Mumbai	12.7.99 to 9.9.99
Rajat K. Bhaduri	Mc. Master University, Hamilton, Ontario, Canada	5.8.99 to 7.8.99
S. V. Ramanan	Univ. New York, Stony Brook	7.8.99 to 14.8.99
N. Mukunda	IISc, Bangalore	13.8.99 to 15.8.99
Bireswar Basu Mallick	SINP, Calcutta	15.8.99 to 25.8.99
Samuel Segun Okoya	Obafemi Awolowo University, Ile-Ife, Nigeria	23.8.99 to 22.11.99
Andreas Rosenschon	University of Genoa, Italy	29.8.99 to 5.9.99
Sudhakar Yarlagadda	SINP, Calcutta	31.8.99 to 2.10.99
Rashmi Ray	City College of New York	6.9.99 to 8.9.99
A. N. Mohapatra	University of Goa	13.9.99 to 17.9.99

M. Sivakumar	University of Hyderabad.	27.9.99 to 3.10.99
Sourendu Gupta	TIFR, Mumbai	20.10.99 to 26.10.99
Anirban Pathak	Visva Bharati, Santiniketan	14.11.99 to 23.11.99
J. Saint Jean Paulin	University of Metz, France	19.11.99 to 4.12.99
Md. Aleemuddin Siddiqui	ISI, Calcutta	23.11.99 to 25.12.99
Y. Guivarc'h	University of Rennes, France	1.12.99 to 4.12.99
S. I. Khondaker	Dhaka University, Bangladesh	2.12.99 to 8.12.99
S. Umasankar	IIT, Mumbai	6.12.99 to 20.12.99
Jeeva S. Anandan	University of South Carolina, Columbia, USA	7.12.99 to 18.12.99
M. P. Das	Australian National University, Canberra	12.12.99 to 13.12.99
A. P. Balachandran	Syracuse University, New York	12.12.99 to 17.12.99
L. Danzer	University of Dortmund, Germany	19.12.99 to 21.12.99

Sachindeo Vaidya	TIFR, Mumbai	10.1.00 to 16.1.00
Sankalpa Ghosh	JNU, New Delhi	16.1.00 to 19.1.00
M. Ram Murty	Queens University, Ontario, Canada	17.1.00 to 23.1.00
Raghavan Rangarajan	PRL, Ahmedabad	18.1.00 to 26.1.00
L. Damascelli	University of Rome, Tor Vergata, Italy	24.1.00 to 27.1.00
S. A. Khan	University of Padova, Italy	29.1.00 to 29.2.00
Modesto Pusterla	University of Padova, Italy	31.1.00 to 3.2.00
Anirban Mukhopadhyay	MRI, Allahabad	4.2.00 to 5.3.00
Pritiraj Mohanty	Caltech, USA	6.2.00 to 11.2.00
Bruno Kahn	CNRS, France	6.2.00 to 13.2.00
Lorenz Schneider	Université de Paris VII	13.2.00 to 2.3.00
S. D. Adhikari	MRI, Allahabad	14.2.00 to 4.3.00
Abhay Ashtekar	Penn State	23.2.00 to 25.2.00
Haridas Banerjee	SNBNCBS, Calcutta	23.2.00 to 25.2.00

Richard Epp	RRI, Bangalore	23.2.00 to 26.2.00
Rossen Dandoloff	University of Cergy Pontoise, France	23.2.00 to 26.3.00
Bugeaud, Yann	University of Strasbourg, France	29.2.00 to 13.3.00
Surajit Sengupta	IGCAR, Kalpakkam	23.3.00. to 25.3.00
M. Murugan	American College, Madurai	3.4.00. to 2.6.00
K. J. Thomas	Cambridge University, USA	11.4.00 to 12.4.00
R. Rajaraman	JNU, New Delhi	13.4.00 to 22.4.00
Juliet Britto	Mangalore University, Mangalagangotri	14.4.00 to 14.5.00
Joseph Samuel	RRI, Bangalore	25.4.00 to 30.4.00
G. V. R. Babu	Andhra University, Visakhapatnam	1.5.00 to 30.6.00
Shripad M. Garge	MRI, Allahabad	15.5.00 to 17.7.00
A. P. Balachandran	Syracuse University, USA	25.5.00 to 30.6.00
Guruprasad Kar	ISI, Calcutta	27.5.00 to 5.6.00

Shobh Nath Singh	T.D.P.G. College, Jaunpur, U.P.	30.5.00 to 5.6.00
Remy Y. Denis	Gorakhpur University, Gorakhpur	30.5.00 to 5.6.00
Parampreet Singh	IUCAA, Pune	31.5.00 to 8.7.00
S. M. Hegde	REC, Suratkal	31.5.00 to 1.8.00
Heather Russell	MRI, Allahabad	7.6.00 to 29.6.00
Vijayalaxmi Trivedi	TIFR, Mumbai	19.6.00 to 14.7.00
S. Thangavelu	ISI, Bangalore	29.6.00 to 30.6.00
S. Ramanan	TIFR, Mumbai	8.7.00 to 11.7.00
Aninda Sinha	University of Cambridge, England	14.7.00 to 21.7.00
V. Kumar Murty	University of Toronto	14.7.00 to 9.8.00
A. P. Balachandran	Syracuse University	19.7.00 to 23.7.00

2.12 Honours and Awards

Kesavan, S. was awarded the Tamil Nadu Scientist Award (TANSA) for Mathematical Sciences, for 1998, by the Tamil Nadu State Council for Science and Technology.

Kesavan, S. was awarded the C. L. Chandna Award for contributions to mathematical research and teaching, for 1999.

Paranjape, K. H. was elected Fellow of the National Academy of Sciences, Allahabad, in 1999.

Chapter 3

Computer Facilities

The following is a list of acquisitions and upgrades made for the computer system of the Institute.

- A SunWorkstation Ultra-60 dual processor UltraSPARC-II@450MHz system with 512MB RAM operating under Solaris-7 O/S was acquired for analytical/numerical computational purposes.
- University S/W pack containing Fortran 77 & 90, C & C++, SPARC works with 25-user license on the network has been upgraded to version 5 under Solaris O/S.
- Two Linux based P-III multimedia systems (willow and banyan) were added to the network.
- The LANL archive mirror at IMSc has been upgraded to a HP-Netserver-LC3 with P-III@550MHz of with 128MB RAM and 2x9.1GB HDD.
- The old dial-in modems have been replaced with E56K Cyber Bullet modems.
- *Mathematica* was upgraded to version 4 with a 5 user network license, installed under Solaris, IRIX and Linux operating systems.
- Fortran compilers Lahey Fortran 95 with IMSL have been installed on the Linux O/S systems. Pro-Fortran from Absoft has also been installed in our Linux cluster and various other linux desktop machines.

Dr. S. Suresh Rao resigned from his post as ERNET Project staff on May 31, 2000 and Dr. S. Arun Kumar was appointed in his place.

Chapter 4

The Library

During the year 1999-2000, three thousand five ninety six volumes have been added to the Library which brings the total volumes to 42,457 as on 31.3.2000. The Library continues to subscribe to about 260 International Journals on Mathematics, Physics and Theoretical Computer Science.

In addition to books and journals, library receives a good number of preprints from different institutions both within and outside the country. It is used not only by the scientists of this Institute but also by others.The NBHM has recognised this library as the Regional Library for mathematics. The library has access to some **online journals** and contents pages of a few other journals which are listed below:

- Conformal Geometry and Dynamics
- Journal of the AMS
- Mathematics and Computation
- Proceedings of the AMS
- Representation Theory
- Transactions of the AMS
- Nuclear Physics A & B
- Nuclear Physics B Proceedings Supplements
- Physica A - E
- Physical Review A - E
- Physical Review Letters
- Physics Letters A & B
- Optics Letters
- J. of the Optical Society A & B
- Inventiones Mathematicae

- Numerische Mathematik
- Mathematische Annalen
- Mathematische Zeitschrift
- European Physical Journal A - D
- Communications in Mathematical Physics
- Acta Informatica
- Archive for Rational Mechanics and Analysis

The access is restricted to Institute members only.

Services

Apart from acquiring the books recommended by the users, the library offers reprographic and inter library borrowing services. Using LIBSYS software, the library catalogue has been computerized and is now available online to the readers both within and outside the Institute.

Acknowledgements

The library gratefully acknowledges the donation of valuable books and journals received during the current year from the persons/organisations mentioned below:-

M/s Allied Publishers
Door Programme
ICTP, Italy
NBHM
Researchco Periodicals
Dr. M. Fellows, Univ. Victoria, Canada
Dr. Mahan Mitra, Sri Ramakrishna Mission
Dr. N. K. Mondal, TIFR
Dr. M. Walschmidt, Univ. Paris VI
Dr. V. Arvind, IMSc
Dr. Kalyana Rama, IMSc
Dr. Krishna Maddaly, IMSC
Dr. R. Ramachandran, IMSC
Dr. V. Raman, IMSc
Dr. Sumen Roy, IMSc
TCS Group, IMSc