HARISH-CHANDRA RESEARCH INSTITUTE

ACADEMIC REPORT
(2005-06)

Chhatnag Road , Jhunsi , Allahabad - 211 019 , India

CONTENTS

About the Institute

The Early Years

Till 10th October 2000 the Institute was known as the Mehta Research Institute of Mathematics and Mathematical Physics (M.R.I). On 11.10.2000 it was renamed as Harish-Chandra Research Institute (H.R.I) after the mathematician, late Prof. Harish-Chandra.

The Institute started with the efforts of Dr. B. N. Prasad, a mathematician at the University of Allahabad, who obtained the initial support from the B. S. Mehta Trust, Kolkata. Dr. Prasad was succeeded in January 1966 by Dr. S. R. Sinha, also of Allahabad University. He was followed by Prof. P. L. Bhatnagar, who joined as the first formal Director. On Prof. Bhatnagar's demise in October 1976, the responsibilities were again taken up by Dr. Sinha. In January 1983, Prof. S. S. Shrikhande of Bombay University joined as the next Director of the Institute. During his tenure the dialogue with the Department of Atomic Energy (DAE) entered into the decisive stage and a review committee was constituted by the DAE for examining the future of the Institute. In 1985 the then Chief Minister of Uttar Pradesh, agreed to provide sufficient land for the Institute and the DAE promised financial support for meeting both the recurring and non-recurring expenditure. In January 1992, finally, about 66 acres of land was acquired in Jhunsi, Allahabad.

Prof. Shrikhande was followed by Prof. H. S. Mani who took over as the Director in January 1992. With his joining and, the shift to the new campus at Jhunsi in 1996, the activities of the Institute picked up quickly. This phase of rapid growth is still continuing.

The New Phase

After a distinguished tenure of about nine years Prof. Mani retired in August 2001 and the charge was taken over by Professor Ravi S. Kulkarni. Currently the Director of the Institute is Professor Amitava Raychaudhuri who joined in July 2005. The Institute continues to be devoted to fundamental research in various fields of Mathematics and Theoretical Physics and is a Fully Aided Institute, within the DAE family, Govt of India. Since the year 1992 it has achieved satisfactory progress, as is evident from the recognition received by many of its faculty members, both at the national and international levels. Amongst them, Prof. Ashoke Sen, Prof. D. Prasad, B. Mukhopadhyaya and Dr. D. Choudhury merit special mention. Prof. Ashoke Sen has been elected a Fellow of the Royal Society and also honoured with the Padmashree Award. Prof. B. Mukhopadhyaya was awarded the prestigious S. S. Bhatnagar award in the year 2003. Prof. I.B.S.

Passi was conferred The Distinguished Service Award for the year 2003 on April 13, 2004 from The Mathematical Association of India and awarded the Life-time Service Award by INSA, New Delhi in 2004. Dr. D. Choudhury won the Swarnajayanti Fellowship.

The Institute has a residential campus in Jhunsi, with a very well endowed research library, state of the art computational facilities and fast Internet links to the outside world. There is an active graduate program and a large traffic of visiting scientists and students at the Institute. H.R.I is now considered a premier institute for research in fundamental physics and mathematics in the country.

During the last year Prof. Ashoke Sen, Prof. I.B.S. Passi, Prof. Rajesh Gopakumar, and Prof. Satya Deo have brought further recognition to the institute. Prof. Ashoke Sen was awarded the INSA S.N. Bose Medal, Prof. I.B.S. Passi the Lifetime Services Award by INSA, and Prof. Rajesh Gopakumar the B.M. Birla Science Prize for Physics in 2004. Prof. Satya Deo was given the Distinguished Service Award 2006 by the Mathematical Association of India.

DIRECTOR'S REPORT

2005-06 was a year of transition for the Harish-Chandra Research Institute (HRI). HRI is on the way of becoming a Constituent Unit of the Homi Bhabha National Institute (HBNI) – a Deemed University umbrella for all DAE organization. In this period Professor Ravi S. Kulkarni handed over the charge of Directorship to the undersigned. He continues as a Distinguished Professor of the Institute. The Registrar, Mr. Sanjeev S. Kashalkar, also moved to a position elsewhere.

This is the Birth Centenary year of Shri Girdharilal Mehta - a man who minted millions and who also gave away much of it for noble causes, a benefactor of many organizations, and a visionary. We owe it to Girdharilal-ji's munificence that this Institute came to being at all. To mark this occasion, in collaboration with Bharatiya Vidya Bhavan, an organisation with which Girdharilal-ji had close ties, HRI is planning to hold a joint one-day seminar later this year.

In the past year the Institute has continued to win laurels. I only mention the Satyendra Nath Bose medal bestowed on Ashoke Sen by the Indian National Science Academy, the B.M. Birla science prize in physics won by Rajesh Gopakumar, and the Distinguished Service Award to Prof. Satya Deo from the Mathematical Association of India. It gives us pride that Prof. I.B.S. Passi was chosen for the INSA Senior Scientist position which he opted to take up at Panjab University, Chandigarh as an Emeritus Scientist.

In the past year we have been enriched by the addition of Justin David, Anindya Datta, Asesh Krishna Datta, Manoj Gopalakrishnan, and Sandhya Choubey. Dr. Krishnendu Sengupta had joined us for a brief while before moving to SINP, Kolkata.

HRI is at the threshold of becoming a part of HBNI. In the years ahead, our students will get their degrees from HBNI. Nonetheless, we will enthusiastically continue, and indeed strive to further enhance, our close ties with Allahabad University and the Indira Gandhi National Open University.

In the past year HRI has initiated the HRI-Triveni Lectures. Stalwarts in the fields of mathematics, physics, and related areas will be invited for these lectures. We were very fortunate to have been able to get two very renowned scientists to deliver the first two HRI-Triveni lectures.

1. Professor David Gross (Frederick W. Gluck Professor of Physics at the University of California, Santa Barbara and Director of the Kavli Institute for

Theoretical Physics) visited HRI from January 30 to February 2, 2006. The highlight of his visit was the inaugural HRI-Triveni lecture which he gave on January 31st. Titled "The Future of Physics", Prof. Gross gave a sweeping overview of the diverse questions that physicists are trying to address. Ranging from the microscopic scale to the cosmological and touching on topics in biology and quantum computing, he made a strong case for the vitality of physics as a subject. The lecture was given to a packed auditorium comprising not only of HRI members but also people associated with various academic institutions like Allahabad University, The National Academy of Sciences, India, etc. There was a good deal of press coverage of the event as well as of Prof. Gross' ideas on the challenges before Indian science.

2. The second HRI-Triveni lecturer was Professor Robert Langlands, Hermann Weyl Professor at the Institute for Advanced Study, Princeton, currently Ramanujan Professor at the National Board of Higher Mathematics (NBHM), who visited HRI during February 14–18, 2006. He interacted with many members of the Institute, not only mathematicians but also string-theorists and a large number of students. The second HRI-Triveni lecture, was entitled "Reflections on the Legacy of Harish-Chandra". Prof. Langlands brought out the relevance of Harish-Chandra's work for comtemporary mathematics. More importantly, he emphasied that the only toolkit Harish-Chandra set out with was differential and integral calculus, an unshakable sense of purpose and an unbreakable strength of character. The members of the Institute found it very inspiring to hear, coming as it did from someone who was instrumental in bringing out the full potential of Harish-Chandra's work.

The Institute faculty members have initiated a new programme, planned to become an annual event, in which over a two-day period every member gave a short talk about her/his current research activity. This meeting, held on February 7th and 8th, 2006 was attended by essentially every faculty member and a large number of Ph.D. students. It is hoped that this programme will not only expose the students to the research work being carried out by the HRI faculty, but will also catalyse collaborations within the faculty.

- **Scientific meetings:**

  1. A one day symposium, Einstein 1905, was held on 12th April 2005 to mark the centenary of the *annus mirabilis 1905*, the year in which Einstein wrote three remarkable papers. Among the main speakers were J.S. Bagla, T.K. Das, R. Gopakumar, Namit Mahajan, P. Majumdar, B. Mukhopadhyaya, S. Naik, S. Rao, and Ashoke Sen.

2. Study Group on Extra Dimensions at the Large Hadron Collider: This meeting was organized by B. Mukhopadhyaya, V. Ravindran and Anindya Datta from 7 – 20 June 2005. R. Godbole (IISc, Bangalore), P. Konar (TIFR, Mumbai), A. Kundu (Calcutta University), P. Mathews (SINP, Kolkata), Kumar Rao (TIFR, Mumbai), S. Raychaudhuri (IIT, Kanpur), Utpal Sarkar (PRL, Ahmedabad), S. Sengupta (IACS, Kolkata), participated, besides the faculty, post-doctoral fellows and scholars of HRI.

3. Satellite Symposium on String Theory – Basic Notion and Recent Developments: Under the Platinum Jubilee celebrations of the National Academy of Sciences, India during 1 – 2 October 2005.

4. Ninth Discussion Meeting on Harmonic Analysis: 17 – 19 October 2005.

5. INO Simulation Meeting: during 24 – 26 October, 2005.

6. SERC Preparatory School: 6 – 25 November 2005.

7. International Conference on Infinite Dimensional Lie Algebra and its Applications: 12 – 17 December 2005.

8. International Workshop on Teichmuller Theory and Moduli Problems: Held during 5th to 15th January 2006. This programme was jointly supported by HRI, NSF, DST and Infosys Foundation.

- **Visitors to the Institute:**

  1. Probir Roy, TIFR, Mumbai
  2. Tom Theuns, UK
  3. Amitava Raychaudhuri, Calcutta University
  4. Marc Bourdon, University of Lille
  5. Gautami Bhowmik, University of Lille
  6. Indranil Biswas, TIFR, Mumbai
  7. Amiya Mukherjee, ISI, Kolkata
  8. A. W. Hales, USA
  9. W. J. Harvey, Kings College, London
  10. J. V. Narlikar, IUCAA, Pune
  11. M. S. Narasimhan, TIFR
  12. Denis White, University of Ohio, USA
  13. T. Padmanabhan, IUCAA, Pune
  14. Frank Neumann, University of Leicester, U.K.

15. Siddhartha Gadgil, ISI, Bangalore
16. Urmie Ray, France

- **HRI Colloquia:**

  1. Vinod Gaur: 25.7.05 - Earthquake and Tsunami threats to India.
  2. Jainendra Jain: 4.8.05 - Topological fermions in condensed matter physics.
  3. John Hubbard: 12.8.05 - The dynamics of the forced pendulum.
  4. N.K. Mondal: 24.10.05 - India Based Neutrino Observatory.
  5. C. Muthu: 26.10.05 - Astrophysical Dust : Importance, Nature and Origin.
  6. D.P. Roy: 31.10.05 - Basic Constituents of Matter: Visible and Invisible.
  7. N. Kumar: 15.11.05 - He-4 Supersolid : As Square-root of Normal Solid.

- **Lecture Series:**

  Prof. Siddhartha Gadgil, ISI, Bangalore, gave a series of 6 lectures on Automorphsims of Surfaces during 30th June to 15th July 2005.

  Prof. Urmie Ray, France, gave a series of 3 lectures on Borcherds-Kac-Moody Algebras during 4th July to 18th July 2005.

  Prof. John Hubbard, Cornell University, USA, gave a series of 8 lectures on Complex Dynamics during 3rd August to 15th August 2005.

  Prof. Florian Luca, Mathematical Institute, UNAM Ap, Morelia, Michoacan, Mexico visited during 4.12.05 to 10.12.05 and delivered a lecture on 9.12.05 on Euler's 0 function.

- **Other Activities and Events:**

  1. NBHM Scholarship Test: HRI conducted the National Board for Higher Mathematics written test for M.A./M.Sc. students on 22nd October, 2005 and for Research scholars on 25th February 2006.

  2. VSSP Programme: VSSP (Math) was held during 7th June to 28th June 05. About 35 outside students participated in this programme. Main speakers were S.D. Adhikari, P. Batra, K. Chakraborty, C.S. Dalawat, Satya Deo, R. Dey, R.S. Kulkarni, I.B.S. Passi, B. Ramakrishnan, D. Surya Ramana, Ratnakumar PK, B. Sahu, A.K. Singh and R. Thangadurai.

  VSSP (Physics) was also conducted during the period in which students in batches attended the programme.

  3. Science Talent Search Examination: HRI conducted the Science Talent Search Examination for Secondary schools on 22nd November, 2005.

4. Rajbhasha : A programme for school children in Hindi medium was organised during 4th to 8th July 2005. The Rajbhasha Shield of the DAE for 2004-05 has also been awarded to the Institute in succession for the 2nd year.

5. Founder's Day: Founders Day was celebrated on 19th July 2005. A musical programme was also arranged on this occasion.

6. RMS Lecture Notes Series: The Ramanujan Mathematical Society has started a Lecture Notes Series with an Editorial Board office at HRI. It is funded by DST with a grant of Rs. 35 lakhs for a period of 5 years. One volume on Number Theory edited by Adhikari, Balasubramanian, and Srinivas has already come out.

7. ARIES: An MoU was signed between HRI and Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital to allow faculty-students exchanges.

A. RAYCHAUDHURI
DIRECTOR

GOVERNING COUNCIL

1.	Prof. M.S. Raghunathan (Chairman)	School of Mathematics Tata Institute of Fundamental Research Homi Bhabha Road Mumbai - 400 005
2.	Mr. S.L. Mehta (Vice Chairman)	4, Clive Row Kolkata - 700 001
3.	Dr. C.V. Ananda Bose, IAS (Member)	Joint Secretary (R& D) Govt. of India, DAE Chhatrapati Shivaji Maharaj Marg Mumbai - 400 001
4.	Mr. Rahul Asthana, IAS (Member)	Joint Secretary (F) Govt. of India, DAE Chhatrapati Shivaji Maharaj Marg Mumbai - 400 001
5.	Mr. Rama Kant Mishra (Member)	IAS (Retd.) 23/1E, P.C. Banerjee Road Allen Ganj Allahabad 211 002
6.	Mr. Avnish Mehta (Member)	4 Penn Road Kolkata - 700 027
7.	Prof. R. Balasubramanian (Member)	Director Institute of Mathematical Sciences CIT Campus, Taramani Chennai - 600 113
8.	Dr. J.N. De (Member)	BH-135, Sector-III Salt Lake Kolkata - 700 091

9.	Prof. Narendra Kumar (Member)	Raman Research Institute C.V. Raman Avenue, Sadashivanagar Bangalore 560080
10.	Prof. H.S. Mani (Member)	Visiting Professor Institute of Mathematical Seiences CIT Campus, Taramani Chennai - 600 113
11.	Dr. R.K. Baslas (Member)	Director of Higher Education Uttar Pradesh Allahabad - 211 001
12.	Prof. Amitava Raychaudhuri (Ex-Officio Member)	Director Harish-Chandra Research Institute Allahabad - 211 019

ACADEMIC STAFF

Faculty Members (Mathematics)

1. Prof. S. D. Adhikari
2. Dr. Punita Batra
3. Dr. Kalyan Chakraborty
4. Dr. C. S. Dalawat
5. Dr. Rukmini Dey
6. Prof. Ravi S. Kulkarni
7. Dr. N. Raghavendra
8. Prof. B. Ramakrishnan
9. Dr. D. Surya Ramana
10. Dr. Ratnakumar P. K.
11. Dr. R. Thangadurai

Visiting Professor (Mathematics)

1. Prof. Satya Deo
2. Prof. I. B. S. Passi

Visiting Scientist (Mathematics)

1. Dr. Anirban Mukhopadhyay
2. Dr. Amora Nongkynrih

Visiting Fellow (Mathematics)

1. Dr. Manoj Kumar
2. Dr. M. Prabhakar
3. Dr. Gyan Prakash

4. Dr. Ritumoni Sarma

Research Scholar (Mathematics)

1. Mr. Vikram Aithal
2. Mr. Sanjay Kumar H. Amrutiya
3. Mr. T. V. Anoop
4. Mr. V. V. Awasthi
5. Mr. Kuntal Banerjee
6. Mr. Mohan Namdev Chintamani
7. Mr. Soumya Das
8. Mr. Ratnesh Dixit
9. Mr. Krishnendu Gongopadhyay
10. Ms. Sanoli Gun
11. Mr. Dheeraj Kulkarni
12. Mr. Manish Kumar Mishra
13. Mr. Bhasvin Kumar Moriya
14. Ms. Archana S. Morye
15. Ms. Tanusree Pal
16. Ms. Anupama Panigrahi
17. Ms. Supriya A. Pisolkar
18. Mr. Purusottam Rath
19. Mr. Brundaban Sahu
20. Mr. Siddhartha Sarkar
21. Mr. Mahender Singh
22. Ms. K. Srilakshmi

Faculty Members (Physics)

1. Prof. J. S. Bagla
2. Dr. Sandhya Choubey
3. Prof. D. Choudhury (on lien)
4. Dr. Tapas Kumar Das
5. Dr. Anindya Datta
6. Dr. Asesh K. Datta
7. Dr. Justin R. David
8. Prof. Raj Gandhi
9. Prof. D. Ghoshal
10. Prof. Rajesh Gopakumar
11. Dr. Manoj Gopalakrishnan
12. Dr. Srubabati Goswami
13. Prof. Dileep Jatkar
14. Prof. Pinaki Majumdar
15. Prof. B. Mukhopadhyaya
16. Prof. S. Naik
17. Prof. S. Panda
18. Dr. T. P. Pareek
19. Prof. Sumathi Rao
20. Prof. V. Ravindran
21. Prof. Amitava Raychaudhuri
22. Prof. Ashoke Sen
23. Dr. Prasenjit Sen
24. Dr. L. Sriramkumar

Sr. Research Associate (CSIR)

1. Dr. Ashok Sethia

Visiting Scientist (Physics)

1. Andreas Nyffeler

Visiting Fellow (Physics)

1. Dr. Dumitru Astefanesei
2. Dr. Pravabati Chingangbam
3. Dr. S. S. Deshingkar
4. Dr. Kazuyuki Furuuchi
5. Dr. H.K. Jassal
6. Dr. Namit Mahajan
7. Dr. Vikas Malik
8. Dr. Sukanta Panda
9. Dr. S. K. Rai
10. Dr. Arnab Kumar Ray
11. Dr. K. P. Yogendran

Research Scholar (Physics)

1. Mr. Sanjib Kumar Agarwalla
2. Mr. Arjun Bagchi
3. Mr. Priyotosh Bandyopadhyay
4. Ms. Nabamita Banerjee
5. Mr. Shamik Banerjee
6. Mr. Subhaditya Bhattacharya
7. Mr. Turbasu Biswas

8. Mr. Anindya Dey
9. Mr. Suvankar Dutta
10. Ms. Pomita Ghoshal
11. Mr. Rajesh Kumar Gupta
12. Mr. Sudhir Kumar Gupta
13. Mr. R. Srikanth H.
14. Mr. Rajeev Kumar Jain
15. Mr. Nishikanta Khandai
16. Mr. Girish P. Kulkarni
17. Mr. Swarup Kumar Majee
18. Ms. Ipsita Mandal
19. Ms. Manimala Mitra
20. Mr. Anamitra Mukherjee
21. Mr. Ayan Mukhopadhyay
22. Mr. Kalpataru Pradhan
23. Mr. Jayanti Prasad
24. Mr. Arijit Saha
25. Mr. Bindusar Sahoo
26. Mr. Shashank M. Shalgar
27. Mr. Viveka Nand Singh
28. Mr. Santosh Kumar Swain
29. Mr. Rajarshi Tiwari
30. Mr. Anurag Tripathi

ADMINISTRATIVE STAFF

1.	Shri Sanjeev Kashalkar	Registrar (till 10.11.05)
2.	Shri M.P. Shrivastav	Acting Registrar (from 11.10.05)
3.	Shri Sanjaya Saran	Deputy Registrar (expired 15.12.05)
4.	Shri Raaj Kumar Gulati	Accounts Officer
5.	Shri V.R. Tiwari	Librarian
6.	Shri Prabhat Kumar	Senior Private Secretary
7.	Shri Amit Roy	Internal Audit cum Admn. Officer
8.	Shri K.S. Shukla	Professional Assistant
9.	Shri Jagannath Yadav	Accountant
10.	Shri R.P. Sharma	Guest House Manager
11.	Ms. Archana Tandon	Office Superintendent
12.	Shri Deepak Srivastava	Store Purchase Officer
13.	Shri V.P. Tiwari	Jr. Hindi Translator
14.	Shri Uma Kant Dwivedi	Cashier
15.	Shri D. Malhotra	UDC
16.	Shri K.K. Srivastava	UDC
17.	Shri Yashpal Singh	Steno
18.	Mrs Sumitra	UDC
19.	Shri Parmanand Mishra	Jr. Library Assistant
20.	Shri Dharm Pal Sharma	Jr. Library Assistant
21.	Mrs Seema Agarwal	Receptionist
22.	Shri Kashi Prasad	Driver
23.	Shri Ram Dulare Maurya	Bearer (Canteen Cadre)
24.	Shri Dina Nath Dubey	Bearer (Canteen Cadre)
25.	Shri Lalloo Ram	Bearer (Canteen Cadre)
26.	Shri Kamlesh Thakur	Bearer (Canteen Cadre)
27.	Shri Ramakant Dixit	Watchman/Peon
28.	Shri Kamta Prasad	Watchman/Peon
29.	Shri Rajesh Kumar	Sweeper
30.	Shri Munna Lal	Gardener

Engineering/Technical Staff:

1.	Shri K. Venkatraman	Sr. Consultant (till 29.04.05)
2.	Shri Manish Sharma	Scientific Officer 'C'
3.	Shri R.N. Shukla	Scientific Officer 'D' (till 30.06.05)
4.	Shri Sanjai Verma	Systems Manager
5.	Ms. Anju Verma	Scientific Asstt.
6.	Shri Ajay Kumar Srivastava	Jr. Engineer (Electrical)
7.	Shri V.K. Srivastava	Jr. Engineer (Civil)
8.	Shri Ajaya Srivastava	Jr. Engineer (Electrical) (till 03.01.06)

Medical Consultants/Pharmacists:

1.	Dr. G.S. Sinha	Authorised Medical Consultant
2.	Dr. Bharat Arora	Emergency Medical Officer
3.	Dr. Shanta Gujrati	Emergency Medical Officer
4.	Dr. Md. Osama Jafri (From Mar., 2006)	Emergency Medical Officer
5.	Dr. Nidhi Mishra (From Nov., 2005)	Emergency Medical Officer
6.	Dr. S.D. Pandey	Emergency Medical Officer
7.	Dr. Ruchi Rai	Emergency Medical Officer
8.	Dr. R.R. Saraswat (Till Nov., 2005)	Emergency Medical Officer
9.	Dr. Geeta Shukla (Till Nov., 2005)	Emergency Medical Officer
10.	Dr. Rakesh Verma	Emergency Medical Officer

ACADEMIC REPORT - MATHEMATICS

Sukumar Das Adhikari

Research Summary:

Let $n \in \mathbf{N}$ and assume $A \subseteq \mathbf{Z}/n\mathbf{Z}$. Then the function $E_A(n)$ has been defined (in a joint work with Y. G. Chen, J. B. Friedlander, S. V. Konyagin and F. Pappalardi) as the least $t \in \mathbf{N}$ such that for all sequences $(x_1, \ldots, x_t) \in \mathbf{Z}^t$ there exist indices $j_1, \ldots, j_n \in \mathbf{N}, 1 \leq j_1 < \cdots < j_n \leq t$, and $(\vartheta_1, \cdots, \vartheta_n) \in A^n$ with

$$\sum_{i=1}^{n} \vartheta_i x_{j_i} \equiv 0 \pmod{n}.$$

To avoid trivial cases, one assumes that the weight set A does not contain 0 and it is non–empty.
Similarly, for any such set $A \subset \mathbf{Z}/n\mathbf{Z} \setminus \{0\}$ of weights, we have defined the Davenport Constant of $\mathbf{Z}/n\mathbf{Z}$ with weight A denoted by $D_A(n)$ to be the least natural number t such that for any sequence $(x_1, \cdots, x_k) \in \mathbf{Z}^k$, there exists a non-empty subsequence $\{x_{j_1}, \cdots, x_{j_l}\}$ and $(a_1, \cdots a_l) \in A^l$ such that

$$\sum_{i=1}^{l} a_i x_{j_i} \equiv 0 \pmod{n}.$$

In the above mentioned joint work the following result has been proved:
If $A = \{1, -1\}$, *then* $E_A(n) = n + [\log_2 n]$.
Further work in this direction is in progress.

Publications:

1. *On the sets of uniqueness of a distribution function of* $\{\xi(p/q)^n\}$. (Jointly with P. Rath and N. Saradha) Acta Arith. **119**, 307 – 316 (2005).

2. *Contributions to zero–sum problems.* (Jointly with Y. G. Chen, J. B. Friedlander, S. V. Konyagin and F. Pappalardi) Discrete Math. **306**, 1–10 (2006).

Preprints:

1. *Davenport constant with weights* (Jointly with P. Rath).

Conference/Workshops Attended:

1. Attended the conference *Diophantine Equations* held at TIFR, Mumbai during December 16 - 20, 2005.
2. Attended a conference held in honour of Prof. R. P. Bambah during November 30 – December 3, 2005 at Panjab University, Chandigarh.
3. Attended the conference "Anatomy of integers", held at CRM, Montreal during March 13-17, 2006.

Visits to other Institutes:

1. Visited University of Lille, France, in May 2005 under IFCPAR project.
2. Visited Indian Institute of Science (IISc) in the month of August in 2005.
3. Visited TIFR, Mumbai for about two months during Nov-Dec, 2005.

Invited Lectures/Seminars:

1. Given an invited talk at the Department of Mathematics of University of Littoral, Calais, France on May 30, 2005.
2. Given an invited talk at *Séminaire de Combinatoire Algébrique et Géométrique* at Université Pierre et Marie Curie (Paris 6) on June 2, 2005.
3. Conducted a Summer School on June 27, 2005 at The National Academy of Sciences (India), Allahabad.
4. Given a Compact Course on "Topics in Algebraic Number Fields" during the month of August in 2005 at Indian Institute of Science (IISc), Bangalore as a part of the second thematic programme of their Mathematics Initiative Programme (IMI).
5. Given an invited talk at Burdwan Raj College as the main speaker on a seminar on 26.9.05 during the celebration of 125th Anniversary of the college.
6. Given an invited talk in the symposium on Algebraic Number Theory held at Thakur College, Mumbai, during November 17-19, 2005.
7. Given an invited talk in the conference held in honour of Prof. R. P. Bambah during November 30 – December 3, 2005 at Panjab University, Chandigarh.

8. Given an invited talk in the conference *Diophantine Equations* held at TIFR, Mumbai, during December 16 - 20, 2005.

9. Given a talk at the number theory seminar at the department of Mathematics of Queen's University, Kingston, Canada on March 31, 2006.

Other Activities:

1. Gave a course on Algebraic Number Theory to second year Ph. D. students at HRI.

2. Working as a member of the Board of Studies, Mathematics, in HBNI.

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Punita Batra

Research Summary:

I am trying to classify Integrable modules with finite-dimensional weight spaces for the non-twisted and twisted Toroidal Lie algebras, where the center acts trivially. This is a joint work of mine with S.Eswara Rao and with Tanusree Pal.

Preprints:

1. (With S. Eswara Rao, Tanusree Pal) *Graded Integrable representations for the multi-loop Lie algebras*. (in preparation).

Conference/Workshops Organized:

1. Organized International Conference on *"Infinite Dimensional Lie Algebras and Its Applications"* at H.R.I. from December 12-17, 2005. I was the convener of this conference.

Other Activities:

1. Gave three lectures on "Linear Representations of Finite Groups" at HRI in VSSP programme in June 2005.
2. Gave two lectures on "Functions and Their Graphs" in Hindi in the Rajbhasha programme at HRI in July 2005.
3. Gave a graduate course "Algebra-II" to first year Ph.D students at HRI from January 2006 to mid May 2006.
4. Served on the Transport committee, Rajbhasha committee and on the Graduate Studies committee of H.R.I.

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Kalyan Chakraborty

Research Summary:

Continuing my previous work on the divisibility of class numbers of real quadratic fields, I along with A. Mukhopadhyay and F. Luca have improved a recent result of F. Luca. I am also working on proving the existence of a sequence of real quadratic number fields such that their class groups have exponents with many distinct prime factors. We (with Luca and Mukhopadhaya) have some results in the direction too.

Publications:

1. *Exponents of class groups of real quadratic function fields.* II. Proc. Amer. Math. Soc. 134, N0. 1, (2006).

2. *On the number of Fourier coefficients which determine a Hilbert modular form.* Proceedings of Number Theory Conference, Institute of Mathematics, Waseda University. (2005)

Preprints:

1. *Exponents of class groups of real quadratic fields* (with A. Mukhopadhaya and F. Luca).

2. *Class numbers of real quadratic fields with many distinct prime factors* (with A. Mukhopadhaya and F. Luca).

Conference/Workshops Attended:

1. Workshop on Number Theory and Applications, In memory of Prof. Chengdong Pan, Dec.20–22, 2005, Shandong University, China.

Visits to other Institutes:

1. Visited Shandong University form Dec. 22 to Dec. 30th., 2005.

Invited Lectures/Seminars:

1. Invited to deliver a one hour plenary talk at the the workshop on number theory and application at Shangdong University.

2. Delivered a one hour talk to the graduate students at Shangdong University.

Other Activities:

1. Gave half of one semester course on Analysis to the graduate students at HRI.

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Chandan Singh Dalawat

Research Summary:

Last year, the Chow group of a Châtelet surface over $\mathbf{Q}_2$ was computed. This computation has now been extended to arbitrary finite extensions of $\mathbf{Q}_2$. One of the consequence of the result is the explicit determination of the Chow group of any Châtelet surface over any number field.

It was observed that Fröhlich's condition on the discriminants of finite extensions of dyadic local fields — a generalisation of Stickelberger's congruence condition — is sharp in a precise sense.

Publications:

1. *Some aspects of the functor K_2 of fields*, Journal of the Ramanujan mathematical society, **21** No. 2 (2006), 1–23.

Preprints:

1. *The Chow group of a Châtelet surface over a number field*.
2. *Good reduction, bad reduction*.
3. *The Tao of Mathematics, and Think Locally*.
4. *Numbers and periods*.

Conference/Workshops Attended:

1. *Algebraic geometry and commutative algebra,* Madras, 1–6 August, 2005.

Visits to other Institutes:

1. Indian Statistical Institute, Bangalore, August 8–12, 2005.
2. Tata Institute of Fundamental Research, Bombay, September 1–10, 2005.

Invited Lectures/Seminars:

1. *Serre's reciprocity conjecture,* Visiting students' summer programme, 14 June 2005

2. *Good reduction, bad reduction,* Algebraic geometry and commutative algebra, Madras, 1st August 2005.

3. *The Tao of Mathematics,* Indian statistical institute, Bangalore, 9 August 2005.

4. *Think locally,* Colloquium, Indian statistical institute, Bangalore, 11 August 2005.

5. *Numbers and periods,* Harish-Chandra research institute, Allahabad, 8 February, 2006.

Other Activities:

1. Taught a course on *Local arithmetic*, January–May, 2006.

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Satya Deo

Research Summary:

During the academic year 2005-2006, I have been working mainly on three topics: (i)Cohomological Dimension Theory with respect to different cohomologies, (ii)Torsion in the group of homeomorphisms of the finite product of long lines and and long ray, (iii) The Spline modules. Jointly with V.V.Awasthi, we have been trying to compute all the singular homology groups of the n-dimensional Hawaiian earring. Barrat and Milnor had showed only that these groups are nonzero in infinitely many dimensions, but the actual computation had been an open problem for quite some time. We have succeeded in determining them precisely in several dimensions.The work is in progress.

Jointly with David Gauld, we have now determined completely the mapping class groups of the product of n copies of the long ray (respectively for long line) for any natural number n. The answer turns out to be interesting and also surprising viz., it is just isomorphic to the symmetric group of degree n.

I, with J.K.Maitra, have been studying the properties of spline modules on various polyhedral complexes embedded in the plane, or more generally, in any Euclidean space R^n. In this area, we have proved that under suitable conditions any basis for the spline module on a divided domain can always be extended to a basis when we take a subdivision of that domain. This result seems to be useful in approximation theory. We have also analyzed the freeness of spline modules when we pass on from a divided domain to a subdivided domain.

Publications:

1. *Strongly contractible polyhedra which are not simply contractible at n points for any $n \geq 2$* (with V. V. Awasthi), J. Indian Math Soc 72(2005)75-82.

2. *Freeness of homogenized spline module from a divided domain to a subdivided domain* (with J. K. Maitra),Frontiers in Interpolation and Approximation , Ed N.K.Govil et al. , Taylor and Francis Books (2006).

3. *Hilbert Series of free spline modules* (with J.K.Maitra), J. of Indian Math Soc (2006), to appear.

Preprints:

1. *Freeness of homogenized spline module from a divided domain to a subdivided domain* (with J. K. Maitra),Frontiers in Interpolation and Approximation , Ed N.K.Govil et al. ,Taylor and Francis Books (2006).

2. *Hilbert Series of free spline modules* (with J.K.Maitra), Journ Indian Math Soc (2006), to appear.

3. *An inverse system of nonempty objects with empty limit*, (with V.V.Awasthi), communicated.

4. *Homology and Dimension- Further pathological examples* (with V.V.Awasthi), under submission.

5. *Torsion in the group of homeomorphisms of the product of long rays and long lines* (with David Gauld). (in preparation)

Conference/Workshops Attended:

1. Annual Conference of the Indian Mathematical Society, Roorkee.

2. Annual Conference of the Ramanujan Mathematical Society, Calicut.

3. Annual conference of the Jammu Mathematical Society, Jammu.

4. The Workshop of Principals on Quality Assurance in Higher Education, Jiwaji University, Gwalior.

Visits to other Institutes:

1. IISc, Bangalore for Ph.D.Viva Voce Exam and a lecture.

2. B.H.U. for lectures under their UGC, DRS programme.

3. University of Jammu, Jammu to inaugurate the Annual conference of the Jammu Mathematical Society.

4. Jiwaji University, Gwalior, to participate in a Principal's Workshop on Quality Assurance in Higher Education of NAAC.

5. Rani Durgawati University, Jabalpur to give an invited lecture.

6. University of Calicut to give invited talk in the 20th annual conference of Ramanujan Mathematical Society.

7. IIT, Roorkee to participate in the annual conference of IMS.

8. University of Meerut, Meerut to give invited talk during the annual conference of the International Academy of Physical Sciences.

Invited Lectures/Seminars:

1. Lecture in Maths Department, Indian Institute of Science, Bangalore on "Michael's problem on strict contractibility"

2. Two lectures at the Workshop of Ramanujan Mathematical Society on Algebraic Topology, organized at the Calicut University, Calicut.

3. Two lectures on "Sheaf Theory and Complex Analysis" at the Department of Mathematics, BHU, Varanasi.

4. One popular Lecture on "Poncare's Conjecture and the 3-manifolds" during the Annual conference of the International Academy of Physical Sciences, at the Meerut University, Meerut.

Academic recognition/Awards:

- Distinguished Service Award-2006 given by the Mathematical Association of India for my outstanding contributions in mathematics teaching and research.

- Continue to serve as a member of the National Board of Higher Mathematics (NBHM) and also on some of its committees.

- Elected member of the Council of the Indian Mathematics Society for three years starting from 2006.

- Selected a delegate of the NBHM to attend ICM-2006 in Madrd, Spain.

- Delivered the keynote address during a two-day seminar on Analysis and Approximation theory at the R.D.University, Jabalpur.

- Gave the Inaugural lecture of the Jammu Mathematical Society during Feb 2006.

Other Activities:

1. Organized a lecture by Prof David Gauld of the University of Auckland, New Zealand on Nonmetrizable manifolds and their homeomorphisms.

2. Taught two courses (i) Topology-I and II, first year students, (ii) Homotopy Theory, second year students.

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Rukmini Dey

Research Summary:

I have been doing research on geometric quantization of certain systems like self-dual Yang-Mills and vortex equations on a Riemann surface. I use modifications of Quillen-Witten determinant line bundle for constructing the prequantum line bundles.

In addition, I have been doing research on minimal surfaces – I am trying to answer the following question: given any two real analytic, well behaved curves, which are close enough, is there a minimal surface containing the two of them?

Publications:

1. *Geometric quantization of the moduli space of the self-duality equations on a Riemann surface,* Reports on Mathematical Physics, Vol. 57, no. 2, (2006) pg. 179-188.

Preprints:

1. *Geometric quantization of the hyperKähler structure in the self-dual Yang-Mills on a Riemann surface,* submitted.

2. *Geometric quantization of the moduli space of the vortex equations on a Riemann surface,* submitted.

Conference/Workshops Attended:

1. National String Theory Workshop, I.I.T. Kanpur, 9th October - 16th October, 2005.

2. Einstein's Legacy in New Millenium, Puri, 15th Dec - 22nd Dec, 2005.

3. H.R.I. symposium, 6th Feb- 8th Feb 2006.

Visits to other Institutes:

1. T.I.F.R., Mumbai (two weeks in May, 2005)

2. S.I.N.P., Kolkata (two weeks in June, 1 week in July and December, 2005)

3. I.I.T., Kanpur (4 days in Oct, 2005)

4. I.M.Sc., Chennai (2 days in Jan, 2006)

Invited Lectures/Seminars:

1. *"Geometric quantization of self-dual Yang Mills on a Riemann surface and other systems"*, at S.I.N.P., June 2005 and H.R.I. symposium, Feb 2006.

Other Activities:

1. I have formed a mathematical physics study group in which I have myself presented topics and organized presentations by students.

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Ravi S. Kulkarni

Research Summary :

I have been working on the issues of finiteness of dynamical types of transformations in classical geometries, and the spatial and numerical invariants attached to such transformations, for the past several years. This work has reached a definitive maturity. Besides my own work, one thesis at City University of New York was motivated by these themes. Another thesis at HRI is under progress. There are 4-5 papers planned based on these themes.

Another investigation on arithmetic properties of certain curvature functions was completed.

Preprints:

1. *Dynamical Types of Transformations and Conjugacy of Centralizers in Groups*, (submitted).

2. *Some Curvature Functions and Their Arithmetic Properties*, (submitted).

3. (with Rony Gouraige) *Some Classic Theorems about Division Algebras*, (submitted).

Conference/Workshops Attended:

1. Attended the the Interdisciplinary National Conference on Relativity, at S. P. College, Pune, on (Dec 8-10, 2005) and delivered the keynote address: "1) Was Einstein's intuition mathematical or physical? 2) General Relativity, a Differential Geometer's View".

2. Attended the Annual Foundational School I (NBHM-sponsored ATM Programme), Bhaskaracharya Patishthan, Pune, Dec 2005, delivered 8 lectures each on Algebraic Topology and Differential Geometry.

3. "Evolution of the Idea of Curvature through Euler, Gauss, Riemann, Einstein, and Cartan" Colloquium (March 23, 2006), Bronx Community College, City University of New York, New York, US.

Visits to other Institutes:

1. Queens College, and Graduate Center, City University of New York, New York, US (Feb. 1 – May 31, 2006)

2. Thesis Directed: "Z-classes of Elements in Central Simple Algebras", by Rony Gouraige, City University of New York (April 2006)

Other Activities:

1. Delivered a series of lectures on Riemann Surfaces, at HRI, August- November, 2005.

2. Organised (with Prof.s Indranil Biswas (TIFR), and Sudeb Mitra (CUNY, New York) the "International Workshop on Teichmuller Theory and Moduli Problems" Jan 5-15, 2006, at HRI. Delivered a lecture on "Classification of Holomorphic Germs".

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Amora Nongkynrih

Research Summary:

My area of interest is Analytic Number Theory, and have been working on the application of number theory techniques, like sieve methods, to problems in cryptography. I have also been studying *Combinatorics on Words*.

Other Activities:

1. Participated in the VSSP, June 2005, and gave two lectures on *Transcendental Numbers*.

2. Taught the second year graduate course *Analytic Number Theory* during the semester August – December, 2005.

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Gyan Prakash

Research Summary:

Together with Dr. D. Surya Ramana, I determined the number of orbits of largest sum-free sets under the action of $\mathrm{Aut(G)}$ in a finite commutative group G of the form $\oplus_k \mathbf{Z}/n\mathbf{Z}$, where k is an integer ≥ 1 and all prime factors of n are congruent to 1 modulo 3 (such groups are particular cases of what are called type III groups in the relevant literature). This study is reported in the preprint titled *the number of orbits of largest sum-free subsets in certain finite commutative groups*.

Together with Prof. Jean-Marc Deshouillers, I determined the maximum possible cardinality of zero-free subset of $\mathbb{Z}/p\mathbb{Z}$ when p is a sufficiently large prime. For any abelian group G a subset A of G is said to be zero-free if for all nonempty subset B of A we have that $\sum_{b\in B} b \neq 0$. This study is reported in the preprint titled *Large zero-free subsets of* $\mathbb{Z}/p\mathbb{Z}$.

Preprints:

1. *The number of orbits of largest sum-free subsets in certain finite commutative groups*, Gyan Prakash and D.S. Ramana.
2. *Large zero-free subset of* $\mathbb{Z}/p\mathbb{Z}$, Jean-Marc Deshouillers and Gyan Prakash

Conference/Workshops Attended:

1. I attended the conference in honour of Prof. R.P. Bambah, Punjab University, Chandigarh, December, 2005. I gave a talk there on Large sum-free subset of finite abelian group, which is a part of my thesis.
2. I attended conferences in Anatomy of integers as well as conference in Additive combinatorics at University of Montreal, Canada., March-April 2006. I gave a talk there on Large sum-free subset of finite abelian groups, which is a part of my thesis.

Visits to other Institutes:

1. Visited University of Montreal, Canada March-April 2006.

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N. Raghavendra

Research Summary:

I have continued the study of moduli spaces of vector bundles.

Publications:

1. Indranil Biswas and N. Raghavendra, *On transversely holomorphic principal bundles,* Accepted for publication in the Boletín de la Sociedad Matemática Mexicana.

Preprints:

1. Indranil Biswas and N. Raghavendra, *The Atiyah-Weil criterion for holomorphic connections*, submitted for publication.

Other Activities:

1. Taught the second year graduate course *Advanced Complex Analysis (Several Complex Variables)*, second semester, 2005–06.

2. Guided a second year graduate student, Archana Morye, in her project work on *Hodge Theory*, during the first and second semesters, 2005–06.

3. Was a member of the Mathematics Graduate Studies Committee.

4. Was a technical member of the Institute Computer Committee until January, 2006.

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B. Ramakrishnan

Research Summary:

1. On a conjecture of Zagier (with S. Gun and M. Manickam).
In a private discussion, D. Zagier conjectured that there exists a canonical subspace of $M_{k+1/2}(\Gamma_0(4))$, different from the Kohnen's plus space, which is mapped into the space of modular form of weight $2k$ for the full modular group under the Shimura map $\mathcal{S}_1$. In this work we prove this conjecture. It is also observed that $\Theta^{2k+1}(z)$ belongs to this subspace when $k \equiv 2 \pmod 4$.

2. On the Fourier expansions of Jacobi forms of half-integral weight
(with B. Sahu)
Let

$$\phi(\tau, z) = \sum_{\substack{n,r\in\mathbf{Z}\\ r^2\leq 4nm}} c(n,r)e^{2\pi i(n\tau+rz)}$$

be a Jacobi form of weight k, index m for the Jacobi group $\Gamma_0(M)^J$ of level M. Then one can write ϕ as follows.

$$\phi(\tau, z) = \sum_{\mu(2m)} h_\mu(\tau)\theta_{m,\mu}(\tau, z),$$

where

$$h_\mu(\tau) = \sum_{N\geq 0} c_\mu(N)e^{2\pi iN\tau/4m}$$

$$c_\mu(N) = \begin{cases} c(n,r) & \text{if } N = 4nm - r^2, \\ 0 & \text{otherwise,} \end{cases}$$

and

$$\theta_{m,\mu}(\tau, z) = \sum_{\substack{r\in\mathbf{Z}\\ r\equiv\mu \pmod{2m}}} e^{2\pi i(r^2\tau/4m+Nz)}$$

is the Jacobi theta function. It follows that the function ϕ is determined completely by all $h_\mu(\tau)$, $\mu(2m)$. In a recent work, H. Skogman showed that a Jacobi form of integral weight k on the full Jacobi group with square-free index is uniquely determined by any of the associated vector components h_μ. In this work, we generalize the work of Skogman to Jacobi forms of half-integral weight.

Publications:

1. *Relations Among Fourier Coefficients of Certain Eta Products* (with S. Cooper, S. Gun and M. D. Hirschhorn), Integers **5** (2005), A #16, 8 pp. (electronic).

2. *Distribution of quadratic non-residues which are not primitive roots* (with S. Gun, B. Sahu and R. Thangadurai), Math. Bohem. **130** (2005), no. 4, 387–396.

3. *Eichler-Zagier map for Jacobi forms of half-integral weight* (with M. Manickam), Pacific Journal of Mathematics, To appear.

Preprints:

1. *On a conjecture of Zagier* (with S.Gun and M. Manickam).

2. *On the Fourier expansions of Jacobi forms of half-integral weight* (with B. Sahu).

Conference/Workshops Attended:

1. Attended and gave an invited talk in the International Conference on Number Theory and Mathematical Physics, held at the Srinivasa Ramanujan Centre, SASTRA, Kumbakonam, India during December 20-21, 2005.

2. Attended and gave a talk in The 20th Annual Workshop on Automorphic Forms and Related Topics, held at The University of Colorado at Boulder, USA during March 2006.

Other Activities:

1. Guiding two HRI students for their PhD, one of them will be submitting her thesis in April 2006.

2. Convener of the Graduate Studies Committee (Mathematics).

3. Member of Faculty Recruitment Committee (Mathematics).

4. Dean of Administration (since October 2005).

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D. Surya Ramana

Research Summary:

Together with Dr. Gyan Prakash, I determined the number of orbits of largest sum-free sets under the action of $\mathrm{Aut(G)}$ in a finite commutative group G of the form $\oplus_k \mathbf{Z}/n\mathbf{Z}$, where k is an integer ≥ 1 and all prime factors of n are congruent to 1 modulo 3 (such groups are particular cases of what are called type III groups in the relevant literature). This study is reported in the preprint titled *the number of orbits of largest sum-free subsets in certain finite commutative groups*.

I also studied the theory of the large sieve as exposed in the lectures at H.R.I. by Prof. O. Ramare, whom I am assisting in the preparation of a monograph authored by him on the subject based on the aforementioned lectures. It is hoped that this will be relevant to work envisaged in the coming academic year.

Preprints:

1. *The number of orbits of largest sum-free subsets in certain finite commutative groups*, Gyan Prakash and D.S. Ramana.

Conference/Workshops Attended:

1. I attended the conference in honour of Prof. R.P. Bambah, Punjab University, Chandigarh, December, 2005. I gave a talk there on Vinogradov's elementary method.

Visits to other Institutes:

1. Visited I.M.Sc. Chennai in July, 2005.

Other Activities:

1. Participated in conducting interviews at the Lucknow in December, 2005 for the K.V.P.Y. fellowship of the Govt. of India.

2. Conducted the mathematics part of the annual science talent examination of H.R.I. for 2005.

3. Served as the Convenor, Library Comm., H.R.I. for 2005-2006. Served as member, Local Works Committee, H.R.I. and member, Medical Committee, H.R.I. for 2005-2006.

4. Assisted the Director, H.R.I. in perparing the XIth plan draft document and, in particular, those parts of this document relating to infra-structure, housing and library requirements.

5. Lectured on Functional Analysis to the students of the second year of the H.R.I. graduate programme in the semester August-December, 2005.

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Ratnakumar P. K.

Research Summary:

I am continuing my study on regularity of solutions on Schrödinger equations on n dimensional Euclidean space, with a general potential.

Publications:

1. *Schrödinger equation and the oscillatory semigroup for the Hermite operator,* Journal of Functional Analysis, (224), 2005, 371-385, (jointly with A. K. Nandakumaran).

Preprints:

1. *Schrödinger propagator for the special Hermite operator.*

Conference/Workshops Attended:

1. 9th Discussion Meeting on Harmonic Analysis, 17-19 October 2005, Organised at HRI Allahabad.
2. International Conference on Operator Theory and Operator Algebras III, 19-22, December 2005. Organised by the Indian Statistical Institute, Bangalore Centre.
3. Conference on "Analysis and its Application", at Banaras Hindu University, 20-22 January 2006.

Visits to other Institutes:

1. Indian Statistical Institute, Bangalore Centre, 19-22 December 2005.
2. Banaras Hindu University, Varanasi, 20-22 January 2006.

Invited Lectures/Seminars:

1. Invited to give a lecture in the International Conference on Operator Theory and Operator Algebras III, held at the Indian Institute of Science, 19-22 December 2005.
2. Invited speaker for the conference "Analysis and its Application", at Banaras Hindu University, 20-22, January 2006, and gave a lecture on Schrödinger equation for the Hermite operator.

Academic recognition/Awards:

- Selected as a reviewer for the Math Reviews of The American Mathematical Society.

Other Activities:

1. Organised the national conference "9th Discussion Meeting on Harmonic Analysis" at HRI from 17-19 th of October 2006
2. Organised the Visiting Student's Study Programme (VSSP 2006), from 5-23rd, June 2006
3. Taught the course, Differential Equations, in the first semester
4. Taught half of the course, Analysis II in the second semester
5. Serving as the convener for the Ph. D. Interview
6. Served in the Guest house, Hostel and Housing Allotment Committee.

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Ritumoni Sarma

Research Summary:

Let K be a finite extention of the field $\mathbf{Q}$ of rational numbers (such a K is called a number field) and let S_∞ be the set of all nonconjugate embeddings of K into the field $\mathbf{C}$ of complex numbers. We refer to these embeddings as *infinite primes* of K. The ring of integers in K is denoted by $\mathcal{O}_K$. The nonzero prime ideals of $\mathcal{O}_K$ are called *finite primes* of K. Let S be a finite set of primes in K containing S_∞. For a prime ideal $\mathfrak{p}$ of $\mathcal{O}_K$, denote by $v_\mathfrak{p}$ the valuation defined by $\mathfrak{p}$. The ring $\mathcal{O}_{K,S} := \{x \in K : v_\mathfrak{p}(x) \geq 0 \text{ for every prime } \mathfrak{p} \notin S\}$ is called the ring of S*-integers* of K. Then $\mathcal{O}_{K,S_\infty} = \mathcal{O}_K$.

For two subgroups H_1 and H_2 in a group, if $H_1 \cap H_2$ is a subgroup of finite index both in H_1 and H_2, then we say that H_1 and H_2 are *commensurable* and we write $H_1 \asymp H_2$. In particular, a group is commensurable with its subgroups of finite index. Let G be a linear algebraic group defined over K. A subgroup Γ of G is called an S*-arithmetic* subgroup of G if $\Gamma \asymp G(\mathcal{O}_S)$.

For any number field K, we show that any S-arithmetic subgroup of $\mathrm{SL}_2(K)$ contains a subgroup of finite index generated by three elements if $\mathrm{card}(S) \geq 2$. We first showed that the ring of S-integers of a non-CM number field is almost generated just by one S-unit. We use this result as a tool to prove the main result. It is expected that under certain higher rank conditions, the S- arithmetic subgroups of any simple semisimple K-group are virtually generated by three elements. The virtual 3-generation of these groups for the case of $S = S_\infty$ was already proved.

Publications:

1. *On Virtual 3-generation of S-arithmetic subgroups of SL_2,* Ritumoni Sarma, to appear in Asian Journal of Mathematics, International Press.

Conference/Workshops Attended:

1. A symposium on the work of Steinberg, during 7-12 November 2005 at HRI, Allahabad.

2. International Workshop on Teichmuller Theory and Moduli Problems, during 5-15 January, 2006, at HRI, Allahabad.

Visits to other Institutes:

1. School of Mathematics, TIFR, Mumbai, during June and July, 2005.

Invited Lectures/Seminars:

1. A symposium on the work of Steinberg, during 7-12 November 2005 at HRI, Allahabad.

Academic recognition/Awards:

- TAA-Harish Chandra Memorial Award 2004-05, TIFR, Mumbai.

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R. Thangadurai

Research Summary:

Let G be a finite abelian group additively written. By $D(G)$, we denote the least positive integer t such that any given sequence S with elements in G of length t has a subsequence whose sum is 0 in G. In the literature, $D(G)$ is called Davenport's constant. It is trivial to see that $D(G) \leq |G|$ and the equality happens if and only if G is a cyclic group. In 1993, Alford, Granville and Pomerance (also, R. Meshulam independently) proved that

$$D(G) \leq n\left(1 + \log \frac{|G|}{n}\right)$$

where n is the exponent of the group G. Using their method, we (jointly with P. Rath and K. Srilakshmi) gave an effective version of the above theorem. More precisely, we obtain an upper bound involving the number of repetitions of the given sequence.

For the group $G = \mathbb{Z}_n^d$ the above upper bound implies $D(G) \leq n(1 + (d-1)\log n)$. In a joint work with Gautami Bhowmik, we could prove that

$$D(\mathbb{Z}_n^d) \leq d^{\omega(n)}(n-1) + 1.$$

Also, in the same paper, we proved that

$$D(G) \leq n_d + n_{d-1} + (C_1 - 1)n_{d-2} + C_1(n_1 + \cdots + n_{d-3})$$

where C_1 is a constant and n_is are the invariants of G. The above theorem is towards proving the following conjecture of Narkiewicz and Silwa, which states that

$$D(G) \leq n_1 + n_2 + \cdots + n_d.$$

Apart from the study of Davenport's Constant and related area, we are exploring the possibility of integer factorization using quadratic and number field sieve methods.

Preprints:

1. P. Rath, K. Srilakshmi and R. Thangadurai, *On Davenport's Constant*, Preprint, 2005.

2. Gautami Bhowmik and R. Thangadurai,*Smooth Numbers and Davenport's constant*, Preprint 2006.

3. R. Thangadurai, Number Field Sieve, Lecture notes, IMI Worshop on Integer Factorization held at IISc, Bangalore during January 18 to February 11, 2006.

Conference/Workshops Attended:

1. Conference on Diophantine equations held at TIFR, Mumbai in December, 2005.
2. IMI Workshop on integer factorization held at IISc, Bangalore during January-February, 2006.

Visits to other Institutes:

1. Visited and lectured at University of Lille, France during May, 2005 under Indo-French programme.
2. Visited and lectured at University of Bordeaux, France in May 2005.
3. Visited and lectured at University of St-Etienne, France in June, 2005.
4. Visited and lectured at Department of Mathematics, IISc, Bangalore under IMI programme in August, 2005.

Invited Lectures/Seminars:

1. Two lectures on Davenport's Constant at the University of Lille, France during May, 2005 under Indo-French programme.
2. One lecture on Olson's Constant at the Univeristy of Bordeaux, France in May 2005 under Indo-French programme.
3. One lecture on Zero-sum problems at the University of St-Etienne, France in June, 2005.
4. Two lectures on Prime numbers and Irreducible polynomials at Department of Mathematics, IISc, Bangalore under IMI programme in August, 2005.
5. Eight lectures on Number field Sieve at the department of mathematics, IISc, Bangalore under IMI workshop on Integer Factorization in January-February, 2006.

Other Activities:

1. **Academic activities.**
   (a) Conducted JEST entrance Examination for the year 2005-2006.
   (b) Conducted VSSP 2005 and gave 10 lectures on Number Theory.
   (c) Gave two lectures in Number Theory seminars.
2. **Journal Referred.** This year I have been referee of the following international journals
   (a) Discrete Mathematics.
   (b) The Journal für die reine und angewandte Mathematik.
3. **Committees served**:
   (a) Computer Committee - Convenor
   (b) Guest House/Shopping Complex Committee - Member
   (c) Mathematics Visitors Committee - Member
   (d) Office Furniture Committee - Member
   (e) HRIRA - Chair Person

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Manoj K. Yadav

Research Summary:

Let G be a finite group. An automorphism f of G is called (conjugacy) class preserving if $f(g) \in g^G$ for all $g \in G$, where g^G denotes the conjugacy class of g in G, i.e., the set of all conjugates $x^{-1}gx$ of g in G. Let $Aut(G)$ denotes the group of all automorphisms of G. Then the set of class preserving automorphisms of G is a normal subgroup of $Aut(G)$. We denote this subgroup by $Aut_c(G)$.

Very recently I worked on the following question:

Question. How the structure of $Aut_c(G)$ reflects the structure of G and vice versa, where G is a finite nilpotent group?

Remark. Since every finite nilpotent group can be written as a direct product of its Sylow p-subgroups, for studying the class preserving automorphisms of finite nilpotent groups it is sufficient to study class preserving of finite p-groups.
I proved the following:
W. Burnside(1913) constructed a group G of order p^6 isomorphic to the group W consisting of all 3×3 matrices

$$M = \begin{pmatrix} 1 & 0 & 0 \\ x & 1 & 0 \\ z & y & 1 \end{pmatrix}$$

with x, y, z in the field $\mathbb{F}_{p^2}$ of p^2 elements. For this group G, $Inn(G) < Aut_c(G)$, where $Inn(G)$ denotes the group of all inner automorphisms of G. He also proved that $Aut_c(G)$ is an elementary abelian p-group of order p^8. This group G is represented by the group W.
For the statement of our main theorem we need the following theorem, which is also of independent interest as it provides a very neat bound for $|Aut_c(G)|$:
Theorem 1. Let G be a non-trivial p-group having order p^n. Then

$$|Aut_c(G)| \leq \begin{cases} p^{\frac{(n^2-4)}{4}}, & \text{if } n \text{ is even;} \\ p^{\frac{(n^2-1)}{4}}, & \text{if } n \text{ is odd.} \end{cases} \tag{1}$$

One can easily notice that equality holds in (1) for the group W. Motivated from this we have the following natural problem:

Problem. Classify all finite p-group G such that equality holds in (1).

For the statement of our main theorem we also need the definition of Camina p-groups. These are the finite p-groups G such that each non-trivial coset $x\gamma_2(G)$ of the derived group $\gamma_2(G)$ is a single conjugacy class x^G in G. Now we state our main theorem.

Theorem 2. Let G be a non-abelian finite p-group of order p^n. Then equality holds in (1) if and only if G is an extra-special p-group of order p^3 when n is odd, and is a Camina special p-group isoclinic to the group W, a group of nilpotency class 3 and order p^4 or a group of order p^6 isoclinic to R, which is the group $\phi_{21}(1^6)$ in the isoclinism family (21) of [1] when n is even.

[1] R. James, The groups of order p^6 (p an odd prime), Math. Comp. **34** (1980), 613-637.

Publications:

1. *Finite groups with many product conjugacy classes,* Israel J. Math., **154** (2006), 29-49. (jointly with Prof. E. C. Dade)

Preprints:

1. *Class preserving Automorphisms of finite p-groups,* Submitted to London Math. Soc. for publication.

Visits to other Institutes:

1. Visited TIFR, Mumbai from October 10 to October 30, 2005.

Invited Lectures/Seminars:

1. (October 2005) Gave a seminar on "Finite groups with many product conjugacy classes" at Dept. of Math., TIFR, Mumbai.
2. (October 2005) " Gave a seminar on "Finite groups with many product conjugacy classes" at Dept. of Math., IIT, Mumbai.
3. (March 2006) Gave a seminar on "Class Preserving automorphisms of Finite p-Groups" at HRI.

Other Activities:

1. I gave a semester course to the first year Pd. D. students on Abstract Algebra at HRI from August 2005 to December 2005.
2. Gave two lectures in VSSP 2005 at HRI.

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Veerendra Vikram Awasthi

Research Summary:

My area of research is **Algebraic Topology**. I have taken a directed reading course on the Sheaf Cohomology and another on Cohomological Dimension Theory with Prof. Satya Deo, my Ph. D. supervisor.

My main interest lies in Cohomological Dimension Theory. At present, I am working on some open problems on that area; mainly the following three questions which were raised by Kuzminov. (i) Whether or not cohomological dimension remains invariant under Stone-Cech compactification? (ii) Whether or not countable sum theorem is valid for locally closed sets? (iii) Whether or not the Urysohn inequality is valid for cohomological dimension?

1. We have worked on the generalisation of the concept of **Strict Contractibility** which was first introduced by E. Michael in 2002. The basic question of E. Michael about finding an AR polyhedra which is not strictly contractible was solved by Dydak et. al. We extended the construction of that example to get a polyhedron X which is strongly contractible to all its points, but is not strictly contractible at least at n number of points for any $n \geq 2$.

   We have also constructed other examples of compact metric spaces which are not polyhedra, but throw more light on the concept of strict contractibility. In particular, we gave examples of compact metric spaces in Euclidean 3-space which are simply contractible at n points for any $n \geq 1$, but are not strongly contractible at those n points. We are working on this concept of strict contractibility to develop it in more generalized way as this concept is very new and it will provide necessary tool to deal with many problems in Algebraic Topology.

2. We have also constructed a concrete example of an inverse system of nonempty objects with empty limit. It has been often quoted, without giving an example, that there are inverse limit systems in which all the objects are nonempty and the connecting maps are onto, but the inverse limit is empty. By our example, it will easily follow that we can have such an inverse system in the category of modules and homomorphisms, category of topological spaces and continuous maps, etc.

3. In the theory of cohomological (or homological) dimensions, it is invariably the $\check{C}$ech cohomology or the sheaf theoretic cohomology which is used. The simple reason for such a preference is the fact that if X is a paracompact Hausdorff space of covering dimension n, then the $\check{C}$ech homology groups

satisfy the property that $H_q(X;G) = 0,\ \forall q > n$ and for all coefficients G. The question as to what happens if one uses some other cohomology or homology theory, was first answered very decisively by Barratt and Milnor. They constructed a compact, connected, metric space X of covering dimension r (for any given $r \geq 2$) which had the surprising property that its singular homology groups $H_q(X;Q)$ with rational coefficients were non-zero for infinitely many values of q greater than r. More precisely, they proved that $H_q(X;Q) \neq 0$ whenever $q \equiv 1 \text{mod}(r-1)$. Consequently, the integral singular homology groups $H_q(X) \neq 0$ for $q \equiv 1 \text{mod}(r-1)$. We have proved their result that $H_q(X) = 0$ for $r < q < 2r-1$. We have also constructed a compact, connected, metric space Y of covering dimension $2r-2$ $(r > 2)$ which has the property that Y is $(r-1)$-connected and $H_q(X;Q) \neq 0,\ \forall q \geq 2r-2$.

Publications:

1. *Strongly Contractible Polyhedra which are not Simply Contractible at n Points for any $n \geq 2$.*(With Satya Deo) Jour.Indian Math. Soc. **72**, (2005), pp.75-82.

Preprints:

1. An Inverse system of nonempty objects with empty limit.
(With Satya Deo).

2. Homology and Dimension - Further pathological examples.
(With Satya Deo).

Conference/Workshops Attended:

1. International Workshop on "Teichmuller Theory and Moduli Problems" organised by Harish-Chandra Research Institute (HRI), Allahabad during January 5-14, 2006.

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Krishnendu Gongopadhyay

Research Summary:

1. Description of completed research

Dynamical types of isometries of hyperbolic space. In a joint work with Ravi S. Kulkarni we have given a finer classification of dynamical types of isometries of hyperbolic space $\mathbf{H}^n$ and have characterized them algebraically.

Classically, based on their fixed points the dynamical types of the isometries of the hyperbolic n-space $\mathbf{H}^n$ were classified as elliptic, parabolic or hyperbolic. If along with the fixed-point one also consider "rotation-angles" of an isometry, the above classification of the dynamical types can be made finer. We have given a classification of dynamical types which is finer than any of the existing classification in the literature. One can also read the dynamical invariants from this classification.

It was an interesting problem to classify these dynamical types algebraically. That is, by looking at a suitable representation of an isometry how to detect its dynamical type? In this research we have given an answer to this question. We have done this by taking the linear representation of the isometry group of $\mathbf{H}^n$ in $O(n,1)$.

In low dimensions, there are three interesting Lie Theoretic isomorphisms. These isomorphisms allow one to identify the identity component of the isometry group of $\mathbf{H}^n$, $n = 2, 3, 5$ with the groups $PSL(2,\mathbb{R})$, $PSL(2,\mathbb{C})$, equivalently, $PGL(2,\mathbb{C})$, and $PGL(2,\mathbb{H})$ respectively. It is natural to ask for algebraic characterization of the dynamical types of elements in these linear groups.

The classical dynamical type of an element in $SL(2,\mathbb{R})$ or $SL(2,\mathbb{C})$ was characterized by its trace. An element A of $SL(2,\mathbb{R})$ is elliptic, parabolic or hyperbolic if and only if $|trace\ A| < 2$, $= 2$, or > 2 respectively. An element A in $SL(2,\mathbb{C})$ is elliptic, parabolic, or hyperbolic if and only if $|trace\ A|^2$ is < 4, $= 4$, or > 4. For $GL(2,\mathbb{C})$, the characterization can be obtained by replacing "trace" by $trace^2/det$ in the condition. With respect to our finer classification of dynamical types (cf. math.GT/0511444) we have found an algebraic characterization of the dynamical types of elements in $GL(2,\mathbb{C})$. Algebraic characterization of dynamical types of orientation-reversing isometries of $\mathbf{H}^3$ has also been obtained. To characterize the dynamical types of elements in $GL(2,\mathbb{H})$, we have used the fact that the group $GL(2,\mathbb{H})$ can be embedded in $GL(4,\mathbb{C})$. Using this embedding we have considered the co-efficients c_i's of the characteristic polynomials of the corresponding elements in $GL(4,\mathbb{C})$ as the conjugacy invariants. The desired algebraic characterization is obtained in terms of suitable fractions of the c_i's and can be found in math.GT/0511444.

In this regard we would like to note that the algebraical characterization of dynamical types of isometries of $\mathbf{H}^4$ was obtained by Parker et al. in *Math. Proc. Cambridge Philos. Soc. 137 (2004), no. 2, 349–361*. Based on Ahlfors' (*Differential Geometry and Complex Analysis (Springer, 1985), 65–73.*), Waterman's (*Adv. in Math. 101 (1993), 87–113*) work Parker et al have done it with respect to a finer classification of dynamical types made by them. In this dimension our classification of the dynamical types almost matches with their classification. However, for $n \geq 5$, there were no finer classification of the dynamical types and complete algebraic characterizations of them as per as the best of our knowledge.

In math.GT/0511444 we have also parameterized the orientation-preserving isometries of $\mathbf{H}^5$ with a fixed dynamical type.

2. Current Research

Conjugacy classes of centralizers in groups. This research is motivated by the following question.

Question. Given a group G what are the ingredients in G that affects the dynamics of any G-action on any set X? In other words, how much the internal structure of G is important to determine the dynamics of G when it acts on any set X?

We think the conjugacy classes of the centralizer of an element is one of the above ingredients. The conjugacy class of the centralizer of an element in a group G is called the *z-class* of the element. They partitioned G into disjoint subsets. Finiteness of z-classes is related to finiteness of dynamical types of transformations in classical geometries over $\mathbb{R}$ or $\mathbb{C}$. The z-classes are also union of conjugacy classes. In general an infinite group could have infinitely many conjugacy classes but there will be only finitely many z-classes. See the thesis of Rony Gouraige, CUNY (2006), for more details and the preprint *Dynamical types and conjugacy classes of centralizers of groups* by Ravi S. Kulkarni for more examples. The study of centralizers of elements in groups and division algebras are also found to be useful in reproving some classical theorems about division algebras, including Wedderburn's Little theorem. We refer to the preprint *Some classic theorems about division algebras* of Gouraige-Kulkarni for more details of this later aspect. In the near future we wish to explore the z-classes of several other families of groups.

Preprints:

1. (with Ravi Kulkarni) *Dynamical Types of Isometries of Hyperbolic Space*, preliminary version available on

   http://arxiv.org/abs/math.GT/0511444

Conference/Workshops Attended:

1. Perspectives in Mathematics, Ramakrishna Mission Vidyamandira, Belur Math, Howrah, February 6-8, 2006.
2. International Workshop on Teichmüller Theory and Moduli Problems, HRI, India, January 5-14, 2006.
3. The Steinberg Festival: Seminars on Algebraic Groups, HRI, November 7-12, 2005.
4. 9th Discussion Meeting on Harmonic Analysis, HRI, October 17-19, 2005.
5. Summer School and Conference on Topology and Geometry of 3-manifolds, ICTP, Trieste, Italy, June 6-24, 2005.

Visits to other Institutes:

1. ICTP, Trieste, Italy
2. Ramakrishna Mission Vidyamandira, Belur Math, Howrah, West Bengal, India.

Invited Lectures/Seminars:

1. I gave a research talk at the "International Workshop on Teichmüller Theory and Moduli Problems" at the HRI, 5-14 January, 2006.

Academic recognition/Awards:

- Got full funding from the ICTP to attend the Summer School and Conference on Topology and Geometry of 3-manifolds, June 6-24, 2005.

Other Activities:

1. **Short courses attended during the year:**
   (a) *A Crash Course on Moduli Spaces of Vector Bundles* by Prof. M. S. Narasimhan (TIFR).
   (b) *Introduction to Holomorphic Dynamics* by Prof. John H. Hubbard (University of Cornell).
   (c) *On Thurston-Nielson Classification of Surfaces* by Prof. S. Gadgil (Indian Institute of Science, Bangalore).

(d) *Introduction to Branched Covering of Riemann Surfaces* by Prof. Ravi S. Kulkarni (HRI and CUNY).

(e) *Introduction to Lie Groups* by Prof. Ramji Lal (Allahabad University).

Organizational activities:

(a) I was a local organizer of the "International Workshop on Teichmüller Theory and Moduli Problems" at the HRI, 5-14 January, 2006.

(b) I created and maintained the following website for the Teichmüller year

http://www.hri.res.in/~teich

(c) I participated in a discussion session "Mathematics research and Teaching in India" chaired by Prof. V. S. Sunder, (IMsc) at HRI, October 19, 2005.

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Sanoli Gun

Research Summary:

Rankin and Swinnerton-Dyer proved that all the zeros of the Eisenstein Series E_k contained in the standard fundamental domain $\mathcal{F}$ lie on the arc $A = \{e^{i\theta} | \frac{\pi}{3} \leq \theta \leq \frac{\pi}{2}\}$. Recently, J. Getz has generalized the method of Rankin and Swinnerton-Dyer to show that modular forms under certain conditions have similar properties. In our work, we prove similar results for certain types of cusp forms, motivated by the work of Rankin. We also give a closed formula for the zeros of a class of cusp forms in terms of the Fourier coefficients following the method of Kohnen. Further, Kohnen showed that the zeros of the Eisenstein series E_k in the standard fundamental domain other than i and ρ are transcendental. In our work, we obtain similar results for a more general class of modular forms, using the earlier works of Kanou, Kohnen and the recent work of Getz. Also, we obtain some interesting consequences regarding the value of the j function evaluated at certain transcendental numbers.

Publications:

1. *On the Zeros of Certain Cusp Forms,* to appear in Math. Proc. Camb. Phil. Soc. **141** (2006), No. 1

2. *Transcendental Zeros of Certain Modular Forms,* accepted in International Journal of Number Theory.

3. *Relations Among Fourier Coefficients of Certain Eta Products* (with Shaun Cooper, B. Ramakrishnan and Michael D. Hirschhorn),
Integers 5 (2005), A #16, 8 pp. (electronic).

4. *Distribution of quadratic non-residues which are not primitive roots* (with B. Ramakrishnan, Brundaban Sahu and R. Thangadurai),
Math. Bohem. **130** (2005), No. 4, 387-396.

Conferences attended :

1. Attended the Conference on "Number Theory and Mathematical Physics", in Srinivas Ramanujan Centre, Kumbakonam, India from 20th December to 21th December, 2005.

2. Visited the Institute of Mathematical Sciences, Chennai for a month in 2005.

Academic recognition / Award :

1. Awarded fellowship from Indo-French Inst. Math. to visit Institut de Mathematiques de Jussieu, Paris.

Other activities:

Would be submitting my Doctoral thesis in April, 2006.

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Purusottam Rath

Research Summary:

For a real number ξ, let $\{\xi\}$ denote the fractional part of ξ. For real numbers $\xi > 0, \theta > 1$, the distribution of the sequence $\{\xi\theta^n\}_{n\geq 0}$ is one of the most intriguing yet very little-understood questions in number theory with a long chequered history. For a fixed θ, it is known (due to Weyl) that the sequence $\{\xi\theta^n\}$ is uniformly distributed in $[0,1]$ for almost all ξ. Similarly, it is also well known (by Koksma) that for a fixed ξ, the sequence $\{\xi\theta^n\}$ is uniformly distributed in $[0,1]$ for almost all real $\theta > 1$. In fact, $\{\xi\theta^n\}$ is uniformly distributed in $[0,1]$ for almost all pairs (ξ,θ). It is quite paradoxical that we do not have a single explicit example of a pair (ξ,θ) for which $\{\xi\theta^n\}$ is uniformly distributed. Almost all of our understanding is restricted to the measure zero exceptional set, i.e. the set of pairs (ξ,θ) for which $\{\xi\theta^n\}$ is NOT uniformly distributed (these set is however uncountable as its Hausdorff Dimension is positive), quite analogous to the case of transcendental numbers. Almost every number on the real line is transcendental, but our knowledge is mostly restricted to the set of algebraic numbers.

Our motivation for studying these sequences has to do with transcendence. The algebraic nature of a real number θ is encoded in its fractional part $\{\theta\}$. A priori we have very few tools to decode $\{\theta\}$. So it makes sense, at least to us, to look at the sequence $\{\theta^n\}$ instead of the single number $\{\theta\}$. Our objective is to explore the possibility of actually deciphering the algebraic nature of θ from the distribution of the sequence $\{\theta^n\}$, say by studying its set of limit points or its distribution functions. To take the simplest case, when θ is such that $||\theta^n|| \to 0$ as $n \to \infty$ (where $||x||$ is the distance of x from its nearest integer), we have a complete understanding when θ is further assumed to be algebraic. Now the set of all real numbers θ satisfying this property is known to be atmost countable and we already have a supply of countably many algebraic integers (the Pisot-Vijayaraghvan numbers)having this property. So the tantalising question is whether there exists a transcendental θ having this property or we can actually take this as a criterion for algebricity. It is about ninety years since Hardy asked this question and we are yet to settle it.

One of the major difficulties in tackling these exponential sequences is the paucity of techniques or tools. Of course, Weyl's criterion is hopeless for such sequences. In our work, we tried to study the distribution functions of these sequences in the hope of getting some insight to their distribution. In certain cases, for instance when θ ia a rational number, we could get some insight, but it appears quite unlikely that study of distribution functions alone will be able to make any

substantial inroad in the understanding of these sequences. Very recently, there have been some exciting progress, mostly due to the works of Zannier, Corvaja , Dubickas, Bugeaud and Adamczewski. For instance, Corvaja and Zannier (*On the rational approximations to the powers of an algebraic number: Solution of two problems of Mahler and Mendès France , Acta Math., (193) (2004), 175 –191.*) have characterised all algebraic numbers θ such that the sequence $(||\theta^n||)$ is dominated by some power l^n $(0 < l < 1)$ for infinitely many n, i.e. $||\theta^n|| \leq l^n$ for infinitely many n. This question was suggested by Mahler in 1957 and it took almost fifty years and a highly non-trivial generalisation of Roth's Theorem(the algebraic number which is approximated is no longer stationary, but is allowed to vary over a finitely generated subgroup of $\bar{\mathbf{Q}}^{\times}$) to settle this question. The proof involves ingenious application of the celebrated Subspace Theorem due to Schmidt and the Skolem-Mahler-Lech Theorem. We note that Corvaja and Zannier also gave constructive examples of transcendental numbers having the above property, a surprising eventuality. It would be really interesting to characterise these transcendental numbers.

Finally, we mention developments in another direction which holds much promise to the understanding of the sequences $\{\xi\theta^n\}$. This involves studying the complexity of the b-adic expansion of the real numbers ξ and θ for natural number b, using the techniques of combinatorics on Words. For instance, the result of Begeaud and Dubickas (*Fractional parts of powers and Sturmian words, C.R. Acad. Sci. Paris, Sér. I (341) (2005), 69–74.*) is the first explicit result on the behaviour of the sequence $\{\xi b^n\}$ where b is a natural number. They show that if the fractional parts $\{\xi b^n\}$, $n \geq 0$, all belong to a semi-open or an open interval of length $1/b$, then ξ is necessarily transcendental and they give a complete characterisation of these numbers in terms of their b-adic expansion.

So our endeavour, in the near future, is to study and understand

1) The classical techniques due to Pisot,Salem,Vijayaraghvan, Boyd and others

2) The theory of Distribution Functions

3) The theory of Diaphontine approximation and Linear recurrences being developed by Corvaja, Zannier and others.

4) Symbolic dynamics and combinatorics on words being developed by Bugeaud, Adamczewski, Dubickas and others

and hope to have some understanding of these illusive objects.

Publications:

1. *On the sets of uniqueness of the distribution function of* $\{\xi(p/q)^n\}$
   (Jointly with S.D.Adhikari and N. Saradha)
   Acta Arithmetica, 119.4 (2005), 307–316.

2. *Zero-sum problems in Combinatorial Number Theory*
   (Jointly with S.D.Adhikari)
   To appear in the proceedings of the conference held in the occasion of Prof.K.Ramachandra's 70th birthday.

Pre-Prints :

1. *A problem on the fractional parts of the powers of* $3/2$ *and related questions.*
   (Jointly with S.D.Adhikari)
   Submitted

2. *On Davenport's Constant*
   (Jointly with K. Srilakshmi and R. Thangadurai)
   Submitted

Conferences/Workshops and Talks :

1. Attended the conference on Diophantine Equations held in TIFR,Mumbai during 16-20 December, 2005.

2. Attended the workshop on "Diophantine Approximation and Heights" in The Erwin Schrodinger International Institute for Mathematical Physics from 28 Feb 2006 to 18 March 2006.

3. Visited the Institut fur Mathematik und Wissenschaftliches Rechnen, Karl-Franzens-Universitat, Graz and gave a talk on 16 March 2006.

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Brundaban Sahu

Research Summary:

1. In his recent paper [Int. J. Math. Math. Sci.](2004), no. 45-48, 2583–2594] H. Skogman showed that when certain components of a vector-valued modular form associated to a Jacobi form of weight k (k is a positive integer) and index m are zero then some of the other components must be zero, where m is a square-free positive integer. More precisely, he showed that a Jacobi form of weight k and square-free index on the full Jacobi group is uniquely determined by any of the associated vector components. We generalize the work of Skogman to Jacobi forms of half-integral weight (Preprint [1]).

   Let k, N be a positive integers and χ be a Dirichlet character modulo $4N$. The $\mathbb{C}$-vector space of Jacobi forms of weight $k+1/2$, index m for the Jacobi group $\Gamma_0(4N) \times \mathbb{Z}^2$ is denoted by $J_{k+1/2,m}(4N, \chi)$.

   For $N \geq 0$, $\mu \pmod{2m}$, define $c_\mu(N)$ as follows:

$$c_\mu(N) := \begin{cases} c_\phi(\frac{N+r^2}{4m}, r) & \text{if } N \equiv \mu^2 \pmod{2m}, \\ 0 & \text{otherwise} \end{cases}$$

   For $\mu \pmod{2m}$ let

$$h_\mu(\tau) := \sum_{N=0}^{\infty} c_\mu(N) e\left(\frac{N}{4m}\tau\right),$$

   For $\alpha \pmod{2m}$, the Jacobi theta function is given by

$$\vartheta_\alpha(\tau, z) = \sum_{\substack{r \in \mathbb{Z} \\ r \equiv \alpha \pmod{2m}}} e\left(\frac{r^2}{4m}\tau + rz\right).$$

   Then the Jacobi form $\phi \in J_{k+1/2,m}(4N, \chi)$ can be expressed as follows.

$$\phi(\tau, z) = \sum_{\mu \pmod{2m}} h_\mu(\tau)\vartheta_\mu(\tau, z).$$

Now we state our results.

Theorem 1.

Let $\phi(\tau, z) \in J_{k+1/2,p}(4N, \chi)$, where p is an odd prime such that $\gcd(N, 2p) = 1$. For some $\alpha, \beta \pmod{2p}$ with $2 \not| \alpha$, $2|\beta$ and $\gcd(\alpha\beta, p) = 1$, if we have $h_\alpha(\tau) = 0$ and $h_\beta(\tau) = 0$, then $\phi(\tau, z) = 0$.

Theorem 2.

Let $\phi(\tau, z) \in J_{k+1/2,p}(4N, \chi)$, where p is an odd prime such that $p|N$. Then among the $2p$ components $h_\mu(\tau)$, λ_χ of them determine the Jacobi form $\phi(\tau, z)$, where

$$\lambda_\chi = \begin{cases} p-1 & \text{if } \chi \text{ is odd,} \\ p+1 & \text{if } \chi \text{ is even.} \end{cases}$$

Theorem 3.

Let $\phi(\tau, z) \in J_{k+1/2,pq}(4N, \chi)$, where p, q are distinct odd primes. Then the components h_α and h_β with $2|\alpha$, $2 \not| \beta$ and $(\alpha\beta, pq) = 1$ determine the associated Jacobi form $\phi(\tau, z)$.

2. In their paper [Abh. Math. Sem. Uni, Hamburg] (1997) 67, 307-314] W. Kohnen and Y. Choie computed the Petersson scalar product $\langle f, [g, E_{k,m}]_\nu \rangle$ of a Jacobi cusp form f against the Rankin-Cohen bracket $[g, E_{k,m}]_\nu$ of a Jacobi form g and an Eisenstein series $E_{k,m}$ explicitly under a certain assumption on the weight of g and k. We generalized this result in the case of Jacobi forms of higher degree (Preprint [2]).

3. With joint work with Binod Kumar Sahoo, we describe maximal elementary abelian subgroups of the symmetric group and the structure of the normalizer of such subgroups (Publication [2]).

Publications:

1. (with S. Gun, B. Ramakrishan, R. Thangadurai) *Distribution of Quadratic non-residues which are not primitive roots,* Math. Bohem. 130 (2005), no. 4, 387-396.

2. (with Binod Kumar Sahoo) *On Maximal Elementary Abelian Subgroups of the Symmetric Group,* J. Appl. Algebra Discrete Struct. 4 (2006), no. 1, 47-56.

Preprints:

1. (with B. Ramakrishnan) *On the Fourier Expansions of Jacobi Forms of Half-Integral Weight.*, (submitted for publication)

2. (with B. Ramakrishnan) *Rankin-Cohen Brackets and Jacobi forms on* $\mathbb{H} \times \mathbb{C}^g$.. (in preparation)

Conferences/Workshops Attended:

1. Attended International Conference on Number Theory and Mathematical Physics (20-22.12.2005) at Srinivas Ramanujan Centre, Kumbakonam.

2. Attended 33rd Annual conference of Orissa Mathematical Society (4-5.2.2006) at Sambalpur Univesity, Sambalpur.

Visits to other Institutes:

1. Visited IMSc, Chennai for a month in December 2005.

Other Activities:

1. Attended 9th Discussion meeting on Harmonic Analysis (17-19.10.2005) in HRI, Allahabad.

2. Gave lectures on Basic Topology and helped in tutorials in HRI VSSP-2005.

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Siddhartha Sarkar

Research Summary:

(1) Let Σ_g be a compact and orientable surface of genus g. Topologically this is the surface of the sphere with g handles attached. One of the most interesting questions is to study the finite groups G which acts effectively on Σ_g and the action preserves the orientation, and we call G a symmetry group of Σ_g. For $g = 0, 1$ these groups are known since long. Hurwitz proved that if $\mu_g(G)$ is the order of G that acts as above then $\mu_g(G) \leq 84(g-1)$, $g \geq 2$. Machlachlan proved (1969) that $\mu_g(G) \geq 8(g+1)$, $g \geq 2$ and moreover both of these bounds can be attained for infinitely many values of g. In fact every finite group can be realized as a group of symmetries of Σ_g.

Now given $g \geq 2$, a natural question is to find out the symmetry groups of Σ_g. However the question is not well posed, since there is no inductive procedure on $g \geq 2$ to answer the question. To understand this better, we can think of the reverse question : given a finite group G, what are possible $g \geq 2$ such that G is a symmetry group of Σ_g.

There were efforts to understand the the minimum genus for various type of groups. In 1988 Kulkarni, proved that there is an $n = n(G)$ so that:
(1) If G acts on Σ_g, then $g \equiv 1 \bmod n$.
(2) for all but finitely many $g \geq 2$ so that $g \equiv 1 \bmod n$, G acts on Σ_g.

The number $(g-1)/n$, where n is as above, is called a reduced genus of G corresponding to g . We denote the minimum reduced genus of G by $\mu_0(G)$ and the maximum steady reduced genus by $\sigma_0(G)$, i.e. whenever $\tilde{g} \geq \sigma_0(G)$, $\tilde{g}$ is a reduced genus of G . Computing the full genus spectrum for a given group is an interesting question. The groups on which these computations are known are (1) cyclic p-groups (Kulkarni, Maclachlan, 1991), (2) elementary abelian p-groups, p-groups of cyclic p-deficiency ≤ 2, groups with MEP (Machlachlan, Talu, 1988), (5) abelian p-groups (Talu, preprint), (6) semi-direct product of a cyclic group of order p with a cyclic group of order q, where p and q are primes (Weaver, 2001). We expect to extend the result for other types of p-groups.
In this connection we have understood that there are some links to the problem with graded Lie algebras associated with the finite p-groups. But this does not suffice to describe the genus spectrum unless it is a p-group of exponent p.
(2) (with Yasemin Talu) The genus increment for finite group actions is also valid for three dimensional handlebodies. A finite group G acts on a handlebody V_g of

genus g via the embedding :

$$\mu : G \longrightarrow \text{Diff}^+(V_g)$$

The upper bound for automorphism groups in this situation is $12(g-1)$, for $g \geq 2$. The stable genus increment is given by $N(G) = |G|/e_s(G)$ where $e_s(G)$ is the least common multiple of the orders of the spherical subgroups of G. Moreover it is true that (Maclachlan, 1995):
(1) If G acts on V_g, then $g \equiv 1 \bmod N(G)$.
(2) for all but finitely many $g \geq 2$ so that $g \equiv 1 \bmod N(G)$, G acts on V_g.

In this connection the genus spectrum is described for finite p-groups of cyclic deficiency 0 and 1 (Maclachlan, 1995). We are interested to understand the same question for other finite p-groups.

Publications:

1. *On Genus Spectrum of p-groups of exponent p and p-groups of maximal class* (to appear in Journal of Group Theory)

Conference/Workshops Attended:

1. Summer School and Conference on Geometry and Topology of 3-manifolds, 6-24 June 2005, ICTP, Italy.

2. International Workshop on Teichmuller Theory and Moduli Problems, 5-15 Jan. 2006, Harish-Chandra Research Institute, India.

Other Activities:

1. Gave one lecture on "Finite p-group actions on Riemann Surfaces" in Harish-Chandra Research Institute, 12th July, 2005.

2. Gave one lecture on "Finite p-group actions on Riemann Surfaces" in International Workshop on Teichmuller Theory and Moduli Problems, 5-15 Jan. 2006, Harish-Chandra Research Institute, India.

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Tanusree Pal

Research Summary:

Let **g** be a simple finite dimensional Lie algebra. A affine Lie algebra is the universal central extension of the loop algebra $\mathcal{G}_1$ = **g**$\otimes$ **C**$[t_1^{\pm 1}]$. The universal central extension of the multiloop Lie algebra, $\mathcal{G}_n$= **g**$\otimes$ **C**$[t_1^{\pm 1}, \ldots, t_n^{\pm}]$ is called a Toroidal Lie algebra. These are examples of Extended Affine Lie algebra.
In a series of papers in the 1980's V.Chari and A.N.Pressley and later S.E.Rao had given a classification of irreducible integrable modules for affine Lie algebras. Prof S.E.Rao has already generalized some of those results for the non-twisted toroidal Lie algebras in the papers:
Classification of irreducible integrable modules for multi-loop algebras with finite-dimensional weight spaces (J.Alg 246,215-225,(2001))
Classification of irreducible integrable modules for toroidal Lie algebras with finite-dimensional weight spaces (J.Alg 277,(2004) 318-348) .
In our present project, jointly with S.E.Rao and P.Batra, we are trying to extend some of the results which hold for the integrable irreducible module of the affine Lie algebras, to modules of the toroidal Lie algebras. Our main aim is to find out when two irreducible modules for the non-twisted toroidal lie algebras on which the center acts trivially, are going to be isomorphic and to find out the graded irreducible modules for the twisted multiloop lie algebras. The later is an extension of P. Batra's paper *Representations of twisted Multi-loop Lie algebras* (J.Alg 272,(2004) 404-416).

Preprints:

1. *Graded Integrable Representations of Multi-loop Lie algebras* (with S.E.Rao and P.Batra). (in preparation)

Conference/Workshops Attended :

1. Infinite Dimensional Lie Algebra and Its Applications, December 2005 , Harish-Chandra Research Institute, Allahabad

Other Activities:

1. Gave one lecture at VSSP 2005 on Number theory.
2. Helped in the organization of Infinite Dimensional Lie Algebra and Its Applications conference at HRI.

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ACADEMIC REPORT - PHYSICS

Dumitru Astefanesei

Research Summary:

The focus of my research is on new aspects of gravitation from a point of view of string theory. I am particularly interested in the physics related to gauge/gravity dualities, D-branes, black holes, and cosmology. During the last year I was working on projects related to black ring thermodynamics, free fields as a string theory, holography, decay of AdS orbifolds, and the attractor mechanism of four-dimensional stationary black holes.

Publications:

1. D. Astefanesei and E. Radu, *"Quasilocal formalism and black ring thermodynamics,"* PRD **73** (2006) 044014 [arXiv: hep-th/0509144].
2. D. Astefanesei, R. B. Mann and C. Stelea, *"Nuttier bubbles,"* JHEP **0601** (2006) 043[arXiv: hep-th/0508162].
3. D. Astefanesei and G. C. Jones, *"S-branes and (anti-)bubbles in (A)dS space,"* JHEP **0506** (2005) 037 [arXiv: hep-th/0502162].

Preprints:

1. D. Astefanesei, K. Goldstein, R. Jena, A. Sen, and S. Trivedi, *" Rotating Attractors,"*, (in preparation)

Conference/Workshops Attended:

1. Summer School: Strings, Gravity, and Cosmology, Perimeter Institute, Waterloo, Canada June 20 - July 8, 2005;
2. Workshop on Gravitational Aspects of String Theory, Fields Institute, Toronto, Canada May 2-6, 2005;
3. Strings 2005, Toronto University, Canada, July 11-16, 2005;
4. National Workshop on String Theory, IIT Kanpur, India;

5. EINSTEIN'S LEGACY IN THE NEW MILLENNIUM, Puri, India December 15- 22, 2005 .

Invited Lectures/Seminars:

1. *"Quasilocal formalism and black ring thermodynamics,"* Waterloo University, Canada.
2. *"Quasilocal formalism and black ring thermodynamics,"* National Workshop on String Theory,IIT Kanpur.
3. *"Boundary black holes in AdS/CFT,"* TIFR, Mumbai.
4. *"Boundary black holes in AdS/CFT,"* ICTP, Trieste, Italy.

Other Activities:

1. I have participated in pheno lunch activities and presented some talks.

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Jasjeet Singh Bagla

Research Summary:

N-Body simulations, vital tools as they are for the study of galaxy formation, make several approximations in order to make computation tractable. We have developed an analytical technique for estimating the effect of using a finite simulation box. We have shown that the amplitude of perturbations is always under estimated as a result of the finite box size, and the correction is larger at scales close to the box size. We have used this technique to estimate the effect on number of virialised haloes that form as a result of gravitational instability. The same technique can be used for a variety of physical applications and we are presently involved in estimating the effects on the rate of major mergers and also on the velocity field. This work has been done with Jayanti Prasad.

Recent observations have shown that the universe is accelerating and it is also nearly flat, i.e., there is no spatial curvature. The accelerated expansion of the universe requires either a cosmological constant or some form of dark energy to drive the acceleration, with $w \equiv p/\rho < -1/3$.

In the absence of significant spatial variation in the dark energy, the key difference between such models and the one with the cosmological constant is that, in general, w is a function of redshift whereas $w = -1$ for the cosmological constant. We have developed optimised numerical methods to explore such models and compare these with the available observations.

With H. K. Jassal and T. Padmanabhan, we have carried out a detailed study with the help of these methods to see if the variation of w with redshift can be detected or ruled out.

We show that observations of anisotropies in the cosmic microwave background radiation are the strongest constraints on models with variation of w. While some variation is allowed, the cosmological constant is favoured by many observations.

We have also shown that the data do not allow much space for the so called *phantom* models with $w < -1$.

Publications:

1. Bagla J. S. and Ray Suryadeep 2005,MNRAS 358, 1076:
   Comments on the size of the simulation box in cosmological N-Body simulations.
2. Bagla J. S., Prasad Jayanti and Ray Suryadeep 2005,MNRAS 360, 194: *Gravitational collapse in an expanding background and the role of substructure I: Planar collapse.*
3. Ray Suryadeep, Bagla J. S. and Padmanabhan T. 2005, MNRAS 360, 546:
   Gravitational collapse in an expanding universe: Scaling relations for two dimensional collapse revisited.
4. Jassal H. K., Bagla J. S. and Padmanabhan T. 2005,Phys.Rev.D 72, 103503: *Observational constraints on low redshift evolution of dark energy: How consistent are different observations?*

Preprints:

1. Bagla J. S. and Prasad Jayanti 2006, astro-ph/0601320: *Effects of the size of cosmological N-Body simulations on physical quantities — I: Mass Function*.
2. Jassal H. K., Bagla J. S. and Padmanabhan T. 2006, astro-ph/0601389: *The vanishing phantom menace*.

Conference/Workshops Attended:

1. Conference of Computational Cosmology, ICTP, Trieste, Italy. May 31 – June 4, 2005.

Visits to other Institutes:

1. IUCAA, Pune. March 9–20, 2006.

Invited Lectures/Seminars:

1. *The Adaptive TreePM code*. June 1, 2005. Invited talk in the conference on computational cosmology, ICTP, Trieste.

2. *Dark Energy and Observational Constraints*. June 13, 2005. Seminar at ICTP, Trieste.

Other Activities:

1. I gave a course on Quantum Mechanics in Aug.-Dec. 2005. This course is meant for students who join HRI for the PhD programme in Physics.

2. Two students did summer project with me in May-July, 2005. Three students did projects during Dec. 2005.

3. I organised training in parallel computing for a group of students and lecturers from the Birla Institute of Technology, Ranchi.

4. I co-organised a school for high school students from the Allahabad and neighbouring areas. Hindi was the medium of instruction in this school. This school was held during July 4–8 2005. I also gave four lectures in this school.

5. We added a 32 node cluster of Pentium computers to the cluster computing facility. System management of the high performance cluster computing facility is done by a group of users led by me.

   More information on this is available at http://cluster.mri.ernet.in/.

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Tapas K. Das

Research Summary:

My research interest lies in the area of relativistic and high energy astrophysics, and analogue gravity models. During 2005 - 2006, I have been working mostly on the following issues:

1) Analogue Hawking radiation from astrophysical black hole accretion

Collaborators: Hrvoje Abraham, RBI, Croatia; Paramita Barai, GSU; USA, Neven Bilić, RBI, Croatia; Surajit Dasgupta, TIFR, India.

We propose that a general relativistic axisymmetric accretion flow around a Schwarzschild or a Kerr black hole can be considered as a natural example of the classical analogue gravity model. We show that multiple acoustic horizons may generate in such flow, leading to the formation of an analogue white hole flanked by two analogue black holes. We also show that the analogue Hawking temperature for such system may exceed the actual Hawking temperature. We found that the spin of the astrophysical black hole (the Kerr parameter) enhances the analogue effect, as well as the analogue Hawking temperature. This is a very important finding because this can directly tell us how the properties of the rotating space time around an astrophysical black hole influences the analogue black hole formation.

2) Shocked accretion flow around spinning black holes

Collaborators: Paramita Barai, GSU, USA; Paul J. Wiita, GSU & Princeton University, USA.

We are working toward modeling a self consistent general relativistic accretion flow in Kerr metric. We study the shock formation mechanism in such accretion flow and also investigate how such shock may drive outflows from the disc. This model will be of great help in explaining the formation and dynamics of accretion powered cosmic jet.

3) The pattern of accretion flow onto our Galactic centre

Collaborators: Bozena Czerny & Monika Mościbrodzka, CAMK, Poland.

The centre of our galaxy harbours a massive black hole, and the surrounding

region including the central black hole is referred as Sgr A* as a whole, after the radio source first discovered at that location. Sgr A* shows frequent flares originating from the direct vicinity of the central black hole. The properties of the flare emission suggest that such flares originate in the innermost part of accretion flow onto the central black hole, and we need to introduce an appropriate theoretical model of accretion to understand the formation and dynamics of such flares. The material accreting onto Sgr A* most probably comes from the nearby stars. We theoretically analyze the pattern of this flow. We show that for the plausible parameter range, such flow may become non-stationary. The inflowing material pile up to form a torus, or a ring. Such geometric structure is unstable, and instability of such pattern can explain the strong variability of the flowing Sgr A*.

4) A dynamical systems study of black hole accretion discs

Collaborators: Soumini Chaudhuri, JU, India; Arnab K. Ray, HRI, India.

We investigate the accretion phenomena on astrophysical black holes from a dynamical systems point of view. For axisymmetric accretion flows with finite advection velocity, a dynamical systems analysis of the critical points has been found to indicate very accurately the nature of those points, for any general pseudo-potential by which the flow is driven on to a Schwarzschild black hole. Not only are the physical properties of the stationary flow solutions (especially the critical solutions) understood better this way, it also allows for a more complete classification of the critical points for a wide range of flow parameters. These results have been compared with those established through numerical integration of the differential equations governing the flow, and this dynamical systems study can be claimed to be a relatively simple alternative mathematical way to study accretion problems of this nature. Furthermore, a time-dependent perturbative analysis reveals that the form of the perturbation equation, for both isothermal and polytropic flows, is free of the choice of any particular pseudo-potential. Under a generically true asymptotic condition, the inviscid flow has been argued to be stable for any case. The perturbation equation has also served the dual purpose of enabling an understanding of the acoustic geometry for inviscid and rotational flows.
We are now applying our dynamical systems analysis to study the general relativistic accretion in Schwarzschild and Kerr metric to investigate the onset of chaotic behaviour in such systems.

5) Galactic microblazar

Collaborators: Surajit Dasgupta & A. R. Rao, TIFR, India.

We examine the X-ray/Radio correlation detected in the low-hard state of several Galactic black hole candidate sources and explain these correlations using a 'Two Component Advective Flow' model. We invoke radial shocks in the accretion disk and derive a relation between the shock location and the outflow rate, convert these derived parameters into observed radio emission. Parameterizing the accretion as two components, one from a classical Shakura-Sunyaev disk and another a 'halo' accretion, we derive a pedagogical X-ray spectral description. We examine the predicted behavior of the radio emission with respect to the X-ray emission, as a function of accretion and outflow parameters. We find that the predicted behavior follows very closely with the observed one, not only with the X-ray/Radio correlation, but also the radio emission behavior during the spectra state transitions. We also find that the X-ray and radio behavior of Cygnus X-3 can be explained only if we assume that the jet emission is highly relativistic and beamed toward the observer, indicating that this source could be very strong candidate to be identified as a Galactic microblazar.

Publications:

1. Das, T. K. (with Dasgupta, S., & Bilić, N.) 2005, *Pseudo-Schwarzschild Spherical Accretion as a Classical Black Hole Analogue*. General Relativity & Gravitation, (37, 1877)

2. Das, T. K. (with Abraham H, & Bilić, N.), 2006, *Acoustic Horizons in an Axially Symmetric Relativistic Accretion*, Classical and Quantum Gravity, 23, 2371.

3. Das, T. K. (with Barai, Paramita & Wiita, P. J.), 2006, *Erratum: The Dependence of General Relativistic Accretion on Black Hole Spin*, Astrophysical Journal Letters, 640, L107.

4. Das, T. K. (with Moscibrodzka, M, & Czerny, B.), 2006, *The pattern of Accretion flow onto Sgr A**, Monthly Notices of the Royal Astronomical Society (To appear, online publication date 13th June 2006, doi: 10.1111/j.1365-2966.2006.10517.x).

5. **Das, T. K.**, 2006, *Astrophysical Accretion as an Analogue Gravity Phenomena*, Invited review article to appear in a special issue of Indian Journal of Physics (A. K. Raychaudhuri memorial volume - I).

Preprints:

1. **Das, T. K.** (with Chaudhury, S., & Ray, A. K.), 2006, *Critical properties and stability of stationary solutions in multi-transonic pseudo-Schwarzschild accretion*, (Submitted).

2. **Das, T. K.** (with Barai, P.) 2006, *Does black hole spin enhance the analogue gravity effect?* (Submitted)

3. **Das, T. K.** (with Bilić, N., & Dasgupta, S.), 2006 *Black Hole Accretion Disc as an Analogue Gravity Model*,

Conference/Workshops Attended:

1. *'Workshop on Fluid Dynamics'*, held at Indian Association of Cultivation of Science, Jadavpur, Calcutta, India, in December, 2005.

2. *'Radiation and Plasma Processes in Stellar Astrophysics'*, held at Theoretical Institute of Advanced research in Astrophysics, Taiwan, in March, 2006.

Visits to other Institutes:

1. Tata Institute of Fundamental Research, Mumbai, India (May - June, 2005).

2. Centre for Theoretical Studies, Indian Institute of Technology, Kharagpur, India (June, 2005).

3. Saha Institute of Nuclear Physics, Calcutta, India (July, 2005).

4. Centre for Relativity & Cosmology, Jadavpur University, Kolkata, India (July, 2005).

5. Indian Association of Cultivation of Science, Jadavpur, Calcutta, India (December, 2005).

6. Burdwan University, Burdwan, West Bengal, India (December, 2005 and February, 2006).

7. Delhi University, Delhi, India (February, 2006).

8. National Tsing Hua University, Taiwan (March, 2006).

9. Theoretical Institute for Advanced Research in Astrophysics, Taiwan (March - May, 2006).

Invited Lectures/Seminars:

1. *Superluminal motion in astrophysical jets*, at 'Einstein 2005' conference at HRI, April, 2005.

2. Group seminar at Tata Institute of Fundamental Research, India, on *Formation and growth of supermassive black holes*, May, 2005.

3. Colloquium at Centre for Theoretical Studies, Indian Institute of Technology, Kharagpur, India, on *Basics of relativistic transonic accretion*. June, 2005.

4. Seminar at Saha Institute of Nuclear Physics, Calcutta, India, on *Transonic behaviour of matter close to the event horizon*. July, 2005.

5. Seminar at Centre for Relativity & Cosmology, Jadavpur University, Kolkata, India, on *Behaviour of matter close to the event horizon*, July, 2005.

6. Seminar at Indian Association of Cultivation of Science, Jadavpur, Calcutta, India, on *Transonic behaviour of general relativistic black hole accretion and its dependence on the black hole spin*, December, 2005.

7. Colloquium at Indian Association of Cultivation of Science, Jadavpur, Calcutta, India, on *Astrophysical black holes: Laboratory to study the special and the general theory of relativity*, December, 2005.

8. A set of three lecture course at 'Workshop on Fluid Dynamics', held at Indian Association of Cultivation of Science, Jadavpur, Calcutta, India, on *Application of fluid dynamics in astrophysics*, December, 2005.

9. Colloquium at Burdwan University, Burdwan, West Bengal, India, on *Astrophysical black holes: Laboratory to study the special and the general theory of relativity*, December, 2005.

10. Orientation lecture delivered to the under-graduate and the post-graduate students of Department of Physics, Burdwan University, on *Research in astrophysical sciences: Pre-requisite, methodology, and the career prospects*, December, 2005.

11. A two lecture series on '*Computational Astrophysics*', in 'UGC Academic Stuff College Meeting' at Burdwan University, Burdwan, West Bengal, India, in Feb, 2006.

12. Seminar on *On Transonic black hole accretion and related phenomena*, at HRI, on the occasion of a three day faculty talk. Feb, 2006.

13. Colloquium at Delhi University, Delhi, India, on *Astrophysical black holes: Natural Laboratory to study the theory of relativity*, Feb, 2006.

14. Seminar at Delhi University, Delhi, India, on *Transonic properties of general relativistic black hole accretion*, Feb, 2006.

15. Colloquium at National Tsing Hua University, Taiwan, on *Astrophysical black holes: Natural laboratory to study the special and the general theory of relativity*, March, 2006.

16. Oral presentation at the workshop 'Radiation and Plasma Processes in Stellar Astrophysics', TIARA, Taiwan, on *Shock formation in accretion disc and related phenomena*, March, 2006.

Academic Recognition/Awards:

- Have been awarded the 'Visiting Faculty Fellowship' from Theoretical Institute in Advanced Research in Astrophysics (TIARA), Taiwan.

Other Academic/Administrative Activities:

1. **Referee's Job:** Served as the referee for:

   (a) Two papers submitted at 'The Astrophysical Journal'.

   (b) Two papers submitted at 'Monthly Notices of the Royal Astronomical Society'.

   (c) One paper submitted at 'Pramana - Journal of' Physics'.

2. **SERC School**: Guest lecturer (tutored and partially taught) in a course in *Differential Geometry and General Theory of Relativity* in 'SERC Preparatory School of Theoretical High Energy Physics', held at HRI in November, 2005. Took twenty four classes and tutorials.

3. **Student Supervision:** Supervised Ms. Soumini Chaudhury, a M.Sc. 1st year student from Jadavpur University, Calcutta. Submitted a paper with her in Monthly Notices of the Royal Astronomical Society.

4. **Lecture Courses:** Lecture Courses given at various meetings/workshops (see list of seminars for detail).

5. **Journal Club Review Talks:** Reviewd the following papers:

   (a) *Spin, 'Accretion, and the Cosmological Growth of Supermassive Black Holes', ApJ, 620, 59, 2006*. April, 2005.

(b) *'Steady shocks around black holes produced by sub-keplerian flows with negative energy' MNRAS, 365, 1405, 2006*, November, 2005.

(c) *'Observational Evidence of Jet Precession in Galactic Nuclei Caused by Accretion Disks', ApJ Letters, 635, L17, 2005*, January, 2006.

6. **Academic Counseling:** In the Physics department of Burdwan University, with the active co-operation of some faculty members of the Physics Department and the Vice Chancellor of the Burdwan University, I have been trying to set up a academic counseling centre for students, one of the main aims of which will be to provide the students an exposure to basic research in Astrophysics taking place in India and abroad.

7. **HRI Internal Duty:** Served as a member in the computer committee of our Institute.

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Anindya Datta

Research Summary:

In the above period I have mainly concentrated on two things: **1. phenomenology of Universal Extra Dimension** In one of the works (with Santosh K. Rai) we have study the dilepton-dijet signal in the dominant Higgs production channel at a linear e+ e- collider. We estimate the effects of Universal Extra Dimension (UED) by a simple analysis of the cross-sections. The heavy Kaluza-Klein excitations of the Standard Model fields in UED can significantly alter the decay properties of the Higgs boson to loop-driven final states. We show that by taking a simple ratio between cross-sections of two different final states this difference can be very easily highlighted.
I another work (in progres, with G. Bhattacharyya, S. K. Majee and A. Raychaudhuri) we have studied the power law running of gauge, Yukawa and quartic scalar couplings in the universal extra dimension scenario where the extra dimension is accessed by all the standard model fields. After compactifying on an S_1/Z_2 orbifold with a radius $R \sim 1\ \mathrm{TeV}^{-1}$, we compute one loop contributions of the relevant Kaluza-Klein (KK) towers to the above couplings up to a cutoff scale Λ. Beyond the scale of inverse radius, once the KK states are excited, these couplings exhibit power law dependence on Λ. As a result of faster running, the gauge couplings tend to unify at a relatively low scale around 30 TeV, and we choose our cutoff also around that scale. We then examine the consequences of power law running on the triviality and vacuum stability bounds on the Higgs mass.

2. Neutrino phenomenology particularly in the context of atmospheric and long-baseline experiments. The favoured resolution of the atmospheric neutrino anomaly involves an oscillation of the muon neutrino to a different state. Current experiments allow for the latter to contain a significantly large fraction of a non-standard flavour. We demonstrate how the next generation of experiments may take advantage of matter effects to resolve this issue

Publications:

1. *SUSY resonances from UHE neutralinos in neutrino telescopes and in the sky.* Anindya Datta, Daniele Fargion, Barbara Mele, Jour. Hi. Ener. Phy. 0509: 007,2005.

Preprints:

1. *Identifying the contributions of universal extra dimensions in the Higgs sector at linear e+ e- colliders.* Anindya Datta, Santosh Kumar Rai, e-Print Archive:*hep-ph/0509277*

2. *What does the ν_μ oscillate into?* Debajyoti Choudhury, Anindya Datta. (in preparation)

Conference/Workshops Attended:

1. International Linear Collider Workshop, 2006, Indian Institute of Science Bangalore.

Other Activities:

1. Taught a cousre on 'Atomic, Nuclear and Molecular Physics' in the ongoing graduate programme of the Institute.

2. Taught a course (12 lectures) on 'Particle Physics and Standard Model, in preparatory SERC School on Theoretical High Energy Physics, November, 2005.

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Asesh K. Datta

Research Summary:

The broad area of my research interest is particle phenomenology expanding over its accelerator and non-accelerator aspects.

In last eight months since I joined the institute my focus has been in the subject of how to achieve a better understanding and interpretation of the findings at the Large Hadron Collider (LHC, the proton-proton collider that would push the energy frontier to 14 TeV) in terms of possible new physics scenarios beyond the accepted Standard Model (SM) of particle physics. This is now considered to be an extremely urgent issue since LHC will start its operation at CERN, Geneva in a little more than a year's time. That LHC will remain to be the only machine of its kind available to us for over a decade makes the issue even more significant.

Few of my recent studies with others dealt with the actual nature and extent of some possible ambiguities that may blur the interpretation of the LHC data (*viz.*, a possible confusion over whether the data signals Supersymmetry (SUSY) or Extra Dimensions). We have, since then, been trying to device possible techniques to resolve the same. Given that our present understanding and hence expectations for a new kind of physics somewhat revolves mainly around variants of scenarios either involving SUSY or Extra Dimensions this kind of confusions may potentially have wider (and complicated) implications in our quest for the unknown. In short, the LHC could provide us with the toughest of the "Inverse Problems" (from the data to the theory) of our times.

Such a realization has inflicted a sense of urgency and the community immediately put itself on a 'hot pursuit' to address the issue in a very systematic and exhaustive manner. The 'preparedness' to face the actual data is fast becoming a rather well-defined measure. Myself, along with the other members of our group, are right now working on with this broad goal in mind. Over last few months we have been working on the theoretical aspects of the problem and further sophistication and optimization of the computing environment which is a prerequisite for our studies.

We have started our research projects with the two graduate students who joined me and one of my colleagues in the group. Our broad area of research involves an in-depth study of the patterns of high-scale non-universalities in SUSY spectrum in the light of the issues discussed above.

For last few months I have also been working with Biswarup Mukhopadhyaya of our group and Debajyoti Choudhury of Delhi University on some aspects of the so called "Split Supersymmetry" scenario. We observe that some characteristic features of this framework can be closely mimicked by a generic kind of alternative physics scenario. We are trying to understand the nature and extent of such faking. The work mainly exploits the model-features though heavily relies on results and inputs from existing studies at the colliders (especially at the future linear colliders).

With Debajyoti Choudhury I have been pursuing some aspects of the so-called Universal Extra Dimensions (UED) scenario at a future linear collider. This work is now in an advanced stage.

Also, with Abdelhak Djouadi from Orsay, France and Monoranjan Guchait from TIFR, Mumbai we have been carrying out a study on a novel production mechanism of SUSY Higgs particles at a future linear collider.

Conference/Workshops Attended:

1. Attended the International Linear Collider Workshop (LCWS) at the Indian Institute of Science, Bangalore during March 9-13, 2006.

Other Activities:

1. During the period I offered reading courses (projects) on Basic Collider Physics to two of our young graduate students who eventually joined our group and one of them has got registered with me.

2. Our long-term research goal with the LHC in mind inevitably requires a versatile and powerful computing environment with significant number of modern softwares on diverse platforms.

3. During the last few months I also devoted a considerable amount of time in our ongoing organizational activities for a Topical Meeting (with international participation) on Physics at the LHC to be held in December, 2006.

4. The other group-effort in which I have been taking immense interest and devoting time is towards having a concrete planning for the proposed Regional Centre for Accelerator-based Particle Physics (or RECAPP) which, if granted, would start soon in the spring of 2007. Necessary base-works from the academic side have already been undertaken.

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Justin R. David

Research Summary :

My research during 2005-2006 has been centered on two distinct aspects of string theory: i) Understanding the gauge/string duality in regimes where the string theory is strongly coupled. ii) The study of the spectrum of dyonic states in certain class of string compactifications with $\mathcal{N} = 4$ supersymmetry.

On the topic of the gauge/string duality, with L.F. Alday, E. Gava and K.S. Narain I developed a string bit formulation of $\mathcal{N} = 4$ Yang-Mills in 4-dimensions which is conjectured to be dual to string theory in Anti-de Sitter space. We showed that the spectrum and the correlations functions of the free, planar Yang-Mills can be written in terms of the discretized string theory. This suggests that the strongly coupled string theory in Anti-de Sitter space has a discrete worldsheet. With R. Gopakumar I studied his approach of recasting any given field theory amplitude as integrals over closed string moduli space. For a class of four point correlators, we showed the the dictionary between Schwinger parameters and the worldsheet moduli yields a candidate four point function in a worldsheet description of strongly coupled string theory in Anti-de Sitter space. This expression obeys the required properties of crossing symmetry and mutual locality of an expected correlator on the string worldsheet.

A proposal for the partition function for dyons which preserve $1/4$ of the $\mathcal{N} = 4$ supersymmetry in a certain class of string compactifications was put forward by D. Jatkar and A. Sen. The formula involves inverse of Siegel modular forms of subgroups of $Sp(2, \mathbb{Z})$. In colaboration with D. Jatkar and A. Sen, I found a product representation for these modular forms, it generalizes the result of Borcherds, Gritsenko and Nikulin for the weight 10 cusp form of the full $Sp(2, \mathbb{Z})$ group. In a later paper with A. Sen, I gave a proof of the proposed formula for the dyon spectrum in the product representation, using the duality symmetries of string theory.

Publications:

1. *"Towards a string bit formulation of $\mathcal{N} = 4$ super Yang-Mills,"* L. F. Alday, J. R. David, E. Gava and K. S. Narain, JHEP **0604** (2006) 014 [arXiv:hep-th/0510264].

2. *"Product representation of dyon partition function in CHL models,"* J. R. David, D. P. Jatkar and A. Sen,JHEP**06** (2006) 064 [arXiv:hep-th/0602254].

Preprints:

1. *"CHL dyons and statistical entropy function from D1-D5 system,"* J. R. David and A. Sen. (in preparation)

2. *"From spacetime to worldsheet: Four point correlators,"* J. R. David and R. Gopakumar. (in preparation)

Conference/Workshops Attended:

1. "National String Theory Workshop, 2005," Indian Institute of Technology, Kanpur (October 2005).

2. "Indo-Israeli workshop on String Theory," Ein Boqeq, Israel (March 2006).

Visits to other Institutes:

1. Institute of Mathematical Sciences, Chennai, (January 2006).

2. Weizmann Institute of Science, Rehovot, Israel, (March 2006).

3. Tel Aviv University, Israel, (March 2006).

Invited Lectures/Seminars:

1. "Spin chains in the AdS/CFT correspondence", Review talk at National String Theory Workshop, Indian Institute of Technology, Kanpur, (October 2005).

2. "Re-counting dyons in CHL models," Physics seminar at Institute of Mathematical Sciences, Chennai, (January 2006).

3. "On the dyon partition function in CHL models," Seminar at the Indo-Israeli workshop on string theory, Ein Boqeq, Israel, (March 2006).

4. "Towards a string bit formulation of $\mathcal{N} = 4$ super Yang-Mills" String seminar at Tel Aviv University, Israel (March 2006).

Other Activities:

1. Supervised half of the string theory project involving 5 students. Topic: Introduction to Supersymmetry.

2. Member: National organising committee of International String Meeting, Puri (2006).

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S.S. Deshingkar

Research Summary:

I had been mainly working in the area of Numerical Relativity. In Numerical relativity we try to solve the Einstein's equations numerically for given initial and boundary condition and then we also try to extract the physical quantities like mass, angular momentum, energy, gravitational radiation etc. from the evolved spacetime. I worked on extraction of gravitational radiation from simulations of spacetimes using characteristic or null cone approach to numerical relativity.

I also started studying the initial boundary value problem in the Cauchy approach to numerical relativity. The aim is to provide appropriate boundary conditions using isolated horizons.

The Cauchy approach is more suitable for evolving the strong field regimes of spacetimes. But most physical quantities like, gravitational radiation are defined properly at null infinity and so the characteristic approach is more suitable for extracting the physics accurately. I am working on matching Cauchy and characteristic codes for extracting the gravitational radiation from the simulations.

Conference/Workshops Attended:

1. 'School on Spectral Methods: Applications to General Relativity and Field Theory' at LUTH, Observatoire de Paris-Meudon, France, from 14-18 November 2005.

Visits to other Institutes:

1. LUTH, Observetorie de Paris-Meudon, France 15 May - 16 June 2005 & November 19-30 2005.

2. Raman Research Institute, Bangalore - 26 December 2005 - 5 January 2006.

Other Activities:

1. I gave two talks for astrophysics journal club and one astrophysics seminar.

2. I attended the workshop on Linux and System Administration at HRI in April 2005.

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Kazuyuki Furuuchi

Research Summary:

I studied large N 't Hooft-Feynman diagrams of gauge theory which are conjectured to correspond to closed string wordsheets in AdS space. In particular, I studied the finite temperature case and how the difference in the phase, namely confined phase and deconfined phase, changes the relevant diagrams, and how it is interpreted in closed string theory, namely as the difference of non-black hole background and black hole background.

Publications:

1. K. Furuuchi, *"Confined Phase In The Real Time Formalism And The Fate Of The World Behind The Horizon,"* Phys. Rev. D **73**, 046004 (2006) [arXiv:hep-th/0510056].

2. K. Furuuchi, *"From Free Fields to AdS – Thermal Case,"* Phys. Rev. D **72**, 066009 (2005) [arXiv:hep-th/0505148].

Preprints:

1. K. Furuuchi, *"Large N Reductions And Holography,"* arXiv:hep-th/0506183 (submitted to Phys. Rev. D)

Conference/Workshops Attended:

1. Workshop on Einstein's Legacy in the New Millennium, Puri, Dec 15-22 2005.

2. National String Theory Workshop 2005 (IIT Kanpur, India) October 9–16, 2005: Talk title "Confined Phase In Real Time Formalism And The Fate Of The World Behind The Horizon".

3. Strings 2005 Toronto Canada July 11–16, 2005: Poster presentation "From Free Fields to AdS – Thermal Case".

Visits to other Institutes:

1. Interdisciplinary Center for Theoretical Study, University of Science and Technology China, March 22-31 2006.

2. University of British Columbia (Canada) July 17-Aug 3 2005.

Invited Lectures/Seminars:

1. Talks at the conferences mentioned above; At ICTS-USTC, UBC.

Other Activities:
Seminars at HRI:

1. "Confined Phase In The Real Time Formalism And The Fate Of The World Behind The Horizon", September 20, 2005.

2. "From Free Fields to AdS – Thermal Case", August 23, 2005.

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Raj Gandhi

Research Summary:

The ordering of neutrino masses is one of the most important unanswered questions in neutrino physics, and is a major goal for several planned experiments. I and my collaborators have studied its possible resolution by the detection of matter effects in muon and antimuon neutrino survival probabilites in atmospheric neutrinos, as measured in Megaton Water Cerenkov detectors.

The origin and reason for break in the cosmic-ray spectrum at energies of around 5 PeV (also known as the Knee) is an unresolved question. At these energies, another issue which is important is the uncertain nature of prompt muon and neutrino fluxes. Predictions for these span two orders of magnitude due to the differences in perturbative QCD models at these energies (much of this stems from the uncertainty in the gluon structure function at low x). Both of these important (and apparently unrelated) issues would be informed by measurements of the muon fluxes in the 10 TeV to 1000 TeV range. We (Sukanta Panda and I) have shown how the pair meter method, based on energy measurements of pair cascades can be used to accomplish this in a high density calorimeter (like INO).

Other work in progress is related to neutrino factory calculations of matter effects, which we hope to finish soon.

Publications:

1. R. Gandhi and S. Panda, *"Probing the cosmic ray 'knee' and very high energy prompt muon and neutrino fluxes via underground muons,"* $arXiv : hep - phy0512179.$(JCAP, to appear)

2. R. Gandhi, P. Ghoshal, S. Goswami, P. Mehta and S. Uma Sankar, *"Earth matter effects at very long baselines and the neutrino mass hierarchy,"* Phys. Rev. D 73, 053001 (2006)

3. A. Datta, R. Gandhi, P. Mehta and S. Uma Sankar, *"Atmospheric neutrinos as probes of CPT violation,"* Published in * Beijing 2004, ICHEP, vol. 1* 287-290

Preprints:

1. R. Gandhi, P. Ghoshal, S. Goswami, P. Mehta and S. Uma Sankar, *"Probing the nu mass hierarchy via atmospheric nu/mu + anti-nu/mu survival rates in Megaton water Cerenkov detectors,"* arXiv:hep-ph/0506145.

2. V. Arumugam *et al.* [INO Collaboration], "India-based Neutrino Observatory: Interim project report. Vol. 1," INO-2005-01

Conference/Workshops Attended:

1. Workshop on Exploring the Physics Frontier at Deep Underground Laboratories, June 23-24, 2005, Institute for Nuclear Theory, University of Washington, Seattle.

Visits to other Institutes:

1. May/June 2005 Theory Group, CERN
2. June 2005 Theory Group, Argonne National Lab, Chicago
3. June 2005 Theory Group, SLAC, Stanford
4. June 2005 Institute for Nuclear Theory, Seattle *July 2005 Theory Group, Brookhaven National Labs, New York*

Invited Lectures/Seminars:

1. June 3, 2005 Theory Seminar, CERN, Geneva
2. June 8, 2005 Theory Seminar, Argonne National Labs, Chicago
3. June 15, 2005 Theory Seminar, SLAC, Stanford
4. June 22, 2005 Theory Seminar, INT, Seattle
5. July 7, 2005 Theory Seminar, Brookhaven National Labs

Other Activities:

1. I am continuing to play an active role in the development and progress of the proposed Indian Neutrino Observatory (INO), both in the study of its physics potential and as a member of its Program Management Committee.
2. I am the Physics Co-ordinator for India (with Uma Sankar) for the International Scoping Study for the Development of future Neutrino Factories.
3. I am guiding Pomita Ghoshal towards her Ph.d. She will be finishing by Summer of 2007. Additionally, I have guided Ayanangsha Sen as a visiting student (IIT Kharagpur).

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Debashis Ghoshal

Research Summary:

The amplitudes for the tree-level scattering of the open string tachyons, generalised to the field of p-adic numbers, define p-adic string theory. This theory has been proved to be useful in understanding the physics of tachyon condensation. Moreover, in the $p \to 1$ limit it is empirically known to approximate the results of boundary string field theory of the ordinary bosonic strings. We revisit this limit from the point of view of real space renormalisation group of the worldsheet theory. It is argued that the string theory based on the p-adic field provide a discretisation of the bosonic string worldsheet and those on its algebraic extensions of increasing degree make this approximation better and lead to a continuum limit. The discretisation here are in terms of Bethe lattices and we discuss resolution of the problem of embedding these apparently infinite dimensional lattices in two dimensions. It is hoped that our ideas will be useful in understanding the role of the elusive closed strings on the p-adic theory.
The Veneziano amplitude proposed for the scattering of mesons is a fascinating object. In order to study its mathematical properties, a quantum deformation of the arithmetic analogue of Veneziano amplitude was defined. A one parameter deformation of the arithmetic Veneziano amplitude was obtained this way. The construction used the q-extended p-adic gamma function. We discussed difficulties with generalising it to higher point amplitudes.

Publications:

1. *NS fivebrane and tachyon condensation*, D. Ghoshal, D.P. Jatkar and M. Kreuzer, J. Math. Phys. **46** 062301 (2005).

Preprints:

1. D. Ghoshal
   Quantum extended arithmetic Veneziano amplitude. (in preparation)

2. D. Ghoshal
   p-Strings vs. strings
   Based on invited talk in the *12th Regional Conference in Mathematical Physics*, Islamabad, Pakistan (2006). (in preparation)

Conference/Workshops Attended:

1. *II Southeastern European Workshop: Challenges Beyond the Standard Model* (BW 2005) at Vrnjačka Banja, Serbia (2005), (Invited Speaker).

2. *Kodaikanal Summer School* of the Indian Institute of Astrophysics at Kodaikanal (2005), (Invited Lecturer).

3. *National Workshop on String Theory* at the Indian Institute of Technology, Kanpur, India (2005).

4. *Einstein's Legacy in the New Millenium* at Puri, India (2005), (Coordinator, String Theory Discussion Session).

5. *12th Regional Conference in Mathematical Physics* at the Centre for Theoretical Physics, Islamabad, Pakistan (2006), (Invited Speaker).

Visits to other Institutes:

1. Albert Einstein Institute, Potsdam, Germany.

2. Tata Institute of Fundamental Research, Mumbai, India.

Invited Lectures/Seminars:

1. *Noncommutativity and B-field in p-string theory* at the *II Southeastern European Workshop: Challenges Beyond the Standard Model* (BW 2005) at Vrnjačka Banja, Serbia (May, 2005).

2. *Quantum Mechanics*, a course of 12 lectures at the *Kodaikanal Summer School* of the Indian Institute of Astrophysics at Kodaikanal (June, 2005).

3. *Exact noncommutative p-soliton*, seminar at the Albert Einstein Institute, Potsdam, Germany (July, 2005).

4. *p-Strings vs. strings*, invited talk in the *12th Regional Conference in Mathematical Physics*, Islamabad, Pakistan (March, 2006).

Other Activities:

1. Taught the course *Quantum Field Theory II* during the semester Aug–Dec, 2005 in the Graduate School at the HRI.

2. Member of the National Organizing Committee of the *Indian String Meeting 2006* (ISM06) to be held in Puri, India in December, 2006.

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Rajesh Gopakumar

Research Summary:

In the last year I have built on my past work of understanding how quantum field theories can organise themselves into closed string theories. A definite proposal for converting field theory correlators into string amplitudes has been given. I have been developing this proposal in several directions. In collaboration with Justin David, we have focussed on the study of four point functions since that is where the stringy behaviour of amplitudes first comes into play. We have understood in a general way how four point functions in free field theory can be re-expressed using Strebel differentials as amplitudes on the string worldsheet. In particular, for a class of four point functions we find that the dual string theory answers are very intriguing and can be expressed in terms of correlation functions of the critical Ising model. This gives a clue about the worldsheet theory of strings dual to weakly interacting gauge theories. I am currently pursuing various aspects which will enable us to concretely understand this worldsheet theory.

With my student, Suvankar Dutta, we have examined another aspect of the gauge theory/gravity correspondence. This is to do with the holographic behaviour of gravity. We have been trying to understand how the holographic behaviour of black hole entropy (manifested in the area dependence of its entropy for instance) is related to the holographic description afforded by a dual gauge theory description, at least in asymptotically AdS spacetimes. We therefore studied the relation between Wald's formula for the black hole entropy, in the presence of higher derivative corrections to Einstein gravity, and the Euclidean action which is directly related ot the gauge theory free energy. The agreement between these two approaches occurs in a non-trivial way as we checked in a number of cases. We also gave a general argument as to why the two approaches should be the same. We are currently attempting to study more general properties of black hole horizon dynamics in a Wald like holographic manner.

Publications:

1. R. Gopakumar, *"From free fields to AdS-III"*, Phys. Rev. D **72**, 066008, (2005)
2. R. Dijkgraaf, R. Gopakumar, H. Ooguri and C. Vafa, *"Baby universes in String Theory"*, Phys. Rev. D **73**, 066002, (2006).

Preprints:

1. Suvankar Dutta, Rajesh Gopakumar, *" On Euclidean and Noetherian entropies in AdS space"*. (in preparation)

2. *"From spacetime to worldsheet: Four point correlators,"* J. R. David and R. Gopakumar. (in preparation)

Conference/Workshops Attended:

1. Einstein Symposium 2005, Library of Alexandria, Egypt, June 2005.
2. Amsterdam Workshop on Quantum Gravity and String Theory, University of Amsterdam, Jun. 2005.
3. Third Crete Regional meeting on String Theory, Kolymbari, Greece, Jun. 2005.
4. Strings 2005, Toronto, Canada, Jul. 2005.
5. National String Theory Workshop, IIT Kanpur, Sep. 2005.
6. "Physics 2005: 100 years after Einstein's Revolution", IIT Kanpur, Oct. 2005.
7. Workshop on Harmonic Analysis, HRI, Oct. 2005.
8. "Einstein's Legacy in the New Millennium", Puri, Dec. 2005.
9. Workshop on Teichmuller theory and Moduli problems, HRI, Jan. 2006.
10. Bathsheva Rothschild Indo-Israeli Workshop on String Theory, Ein Boqeq, Israel, Feb. 2006.

Visits to other Institutes:

1. TIFR, Mumbai, May 2005 (Adjunct Professor).
2. ASICTP, Trieste, Italy, June 2005.
3. University of Amsterdam, June 2005.
4. Perimeter Institute, Waterloo, Canada, Jul. 2005.
5. S. N. Bose Centre, Kolkata, Jul. 2005.
6. IIT Kanpur, Sep. 2005, Nov. 2005.
7. IMSc. Chennai, Jan. 2006.

Invited Lectures/Seminars:

1. String Theory Seminar, TIFR, Mumbai (four seminars), May 2005.
2. Theoretical Physics Colloquium, TIFR, May 2005.
3. Einstein Symposium 2005, Library of Alexandria, Egypt, June 2005.
4. ASICTP, Trieste, Italy, Jun. 2005 (two seminars).
5. Amsterdam Workshop on Quantum Gravity and String Theory, University of Amsterdam, Jun. 2005.
6. Third Crete Regional meeting on String Theory, Kolymbari, Greece, Jun. 2005 (two lectures).
7. Colloquium, S.N. Bose Centre, Kolkata, July 2005
8. National String Theory Workshop, IIT Kanpur, Sep. 2005
9. "Physics 2005: 100 years after Einstein's Revolution", IIT Kanpur, Oct. 2005
10. Workshop on Harmonic Analysis, HRI, Oct. 2005
11. "Einstein's Legacy in the New Millennium", Puri, Dec. 2005
12. Workshop on Teichmuller theory and Moduli problems, HRI, Jan. 2006
13. Bathsheva Rothschild Indo-Israeli Workshop on String Theory, (Survey Lecture), Feb. 2006.

Academic recognition/Awards:

- B. M. Birla Science Prize in Physics for 2004 (announced Dec. 2005).
- Visiting Research Professor at Mathematical Sciences Research Institute (MSRI), Berkeley (Spring 2006).

Other Activities:

1. Invited article,"Space, Time and Einstein" in special Einstein Centenary Issue of *Frontline*, May 15, 2005.
2. Organiser of "Symposium on String Theory" for undergraduates on occasion of National Academy of Sciences, India Platinum Jubilee, (at HRI), Oct. 2005.

3. Serving on National Organising Committee of DAE-Symposium on High Energy Physics, 2006.

In addition at HRI, I have guided visiting students, taught a graduate course on Particle physics and given journal club talks and String Theory seminars. I also gave a talk in the set of talks given at HRI by the faculty in Feb. 2006. I am also serving in a number of academic and administrative committees at HRI.

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Srubabati Goswami

Research Summary:

The neutrino mass hierarchy, presently unknown, is a powerful discriminator among various classes of unification theories. We show that the $\mathrm{P}_{\mu\mu}$ survival rate in atmospheric events can provide a novel method of determining the hierarchy in megaton water Čerenkov detectors. For pathlength and energy ranges relevant to atmospheric neutrinos, this rate obtains significant matter sensitive variations not only from resonant matter effects in $P_{\mu e}$ but also from those in $P_{\mu\tau}$. We calculate the expected muon event rates in the case of matter oscillations with both normal and inverted hierarchy. We identify the energy and pathlength ranges for which resonant matter effects can lead to observable differences between the above two cases. We also estimate the exposure time required to observe this difference and determine the sign of Δ_{31} in a statistically significant manner.

We analyze the constraints on neutrino mass spectra with extra sterile neutrinos as implied by the LSND experiment. The various mass related observables in neutrinoless double beta decay, tritium beta decay and cosmology are discussed. Both neutrino oscillation results as well as recent cosmological neutrino mass bounds are taken into account. We find that some of the allowed mass patterns are severely restricted by the current constraints, in particular by the cosmological constraints on the total sum of neutrino masses and by the non-maximality of the solar neutrino mixing angle. Furthermore, we estimate the form of the four neutrino mass matrices and also comment on the situation in scenarios with two additional sterile neutrinos.

A basis independent formulation of quark-lepton complementarity is implemented at a high scale for quasidegenerate Majorana neutrinos. It is shown that even with the renormalization group evolution in the minimal supersymmetric standard model, the scenario can be consistent with the data provided a nontrivial role is played by the Majorana phases. Correlated constraints are found on these phases and the neutrino mass scale using the current data. We also indicate how future accurate measurements of the mixing angles can serve as tests of this scenario and restrict the values of the Majorana phases.

We explored a novel possibility of determining the input parameters and their uncertainties used for calculation of solar neutrino fluxes using the direct measurement of solar neutrino fluxes. In particular we consider the constraint on f_B, the normalisation factor for the ^8B flux, as obtained from the global analysis of solar and KamLAND data and estimate the values and uncertainties of each in-

put parameter that we get using this. We also consider the future possibilities of measurement of ^7Be and pp neutrino fluxes and discuss if such measurements can help in reducing the uncertainties of one or more input parameters of the Standard Solar Model.

Publications:

1. S. Goswami and A. Y. Smirnov, Phys. Rev. D **72**, 053011 (2005)
2. R. Gandhi, P. Ghoshal, S. Goswami, P. Mehta and S. Uma Sankar Phys. Rev. D **73**, 053001 (2006)
3. A. Dighe, S. Goswami and P. Roy, Phys. Rev. D **73**, 071301 (2006) [arXiv:hep-ph/0602062].
4. S. Goswami and W. Rodejohann, Phys. Rev. D **73**, 113003 (2006) [arXiv:hep-ph/0512234].

Preprints:

1. *"India-based Neutrino Observatory: Interim project report. Vol. 1,"* INO-2005-01 V. Arumugam *et al.* [INO Collaboration],
2. *Probing the nu mass hierarchy via atmospheric nu/mu + anti-nu/mu survival rates in Megaton water Cerenkov detectors*,
   R. Gandhi, P. Ghoshal, S. Goswami, P. Mehta and S. Uma Sankar,
   arXiv:hep-ph/0506145.
3. *Determining parameters of solar model from direct measurement of solar neutrino fluxes*
   Abhijit Bandyopadhyay,Sandhya Choubey,Srubabati Goswami,S.T. Petcov,
   in preparation.

Conference/Workshops Attended:

1. Lepton-Photon 2005, Upsala University, Sweden, June 2005
2. WHEPP9, Institute of Physics, Bhubaneswar, January 2006

Visits to other Institutes:

1. Indian Institute of Mathematical Sciences, Chennai, TPSC visit March 2005.
2. Techniche Universitat Muenchen, 8th July -13th July, 2005, 22nd September, 2005 - 18 August 2006.
3. Tata Institute of Fundamental Research, December 2005

Invited Lectures/Seminars:

1. Global Analysis of Neutrino Oscillation – IMSC, Chennai March 2005.
2. *Neutrino Oscillations and Masses* , Invited Plenary Talk in Lepton-Photon 2005, Upsala, Sweden, June 2005.
3. *Neutrino Oscillations: Aspects and Prospects*, TUM. Germany, December 2005.
4. *Neutrino Oscillations: Aspects and Prospects*, TIFR, Mumbai, December 2005.

Academic recognition/Awards:

- Awarded the Humboldt Research Fellowship for one year from Humboldt Foundation, Germany.
- Principal Collaborator in the BRNS funded project entitled 'Studies of Physics with Magnetized Iron Neutrino Detector' (Principal investigator: Prof. S. UmaShankar, IIT, Mumbai)

Other Activities:

1. Partial supervisation of the Ph.D. work of Pomita Ghoshal.
2. Ujjwal Sinha from IIT, Delhi did a project on "Neutrino Oscillations" with me for a month in May-June 2005.
3. Served (till September 2005) in the computer committee and the medical committee as convener and Transport committee as member.
4. Member of National Organizing Committee of WHEPP 9

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Harvinder Kaur Jassal

Research Summary:

The present day acceleration of the universe has been described by the presence of dark energy, typically a cosmological constant or a scalar field. In the absence of significant spatial variation in the dark energy, the key difference between scalar field models and the one with the cosmological constant is that, in general, the equation of state of dark energy is a function of redshift in the former. It has been known for some time that supernova observations and constraints from structure formation can be combined to put stringent limits on models for dark energy. Several attempts have been made in the past to constrain the equation of state for dark energy, along with other cosmological parameters, using the observations of galaxy clustering, temperature anisotropies in the CMBR and the high redshift supernova. We focus exclusively on constraining the variation of equation of state for dark energy by using a combination of such observations. In particular, we study the effect of a varying equation of state on the angular power spectrum of the CMBR fluctuations. We demonstrate that the combination of WMAP observations and high redshift supernova observations is a very powerful constraint on variations in dark energy, certainly more powerful that either of the observations used in isolation.

In a detailed extension of this analysis, we allow other cosmological parameters to vary. We include constraints from cluster abundance in addition to the supernova and WMAP constraints. We study dark energy models with a constant equation of state parameter (apart from the cosmological constant). We also study the effect of perturbations in dark energy here. We then generalise to models where the equation of state parameter is allowed to vary in a parameterised form and again study these issues. To include constraints from requirements of structure formation, we use the X-ray observations of rich clusters of galaxies. In the combined analysis, we show that allowing dark energy to vary allows for a larger range in other cosmological parameters. There is significant tension between SN and WMAP observations; the best fit model for one is often ruled out by the other at a very high confidence limit. Hence results based on only one of these can lead to unreliable conclusions. Given the divergence in models favored by individual observations, and the fact that the best fit models are ruled out in the combined analysis, there is a distinct possibility of the existence of systematic errors which are not understood.

We demonstrate that the recently released high redshift supernova data from the SNLS (SuperNova Legacy Survey) project is in better agreement with CMB ob-

servations, unlike the earlier data sets which preferred a different class of models altogether. The SNLS data set favours models similar to the ΛCDM model. We illustrate that WMAP observations are, by far, the strongest constraint on models with a varying equation of state parameter for the dark energy component in a flat universe. Further, the better quality of observations of temperature anisotropies in the CMB are less susceptible to systematic effects and this makes it a more reliable probe of cosmological parameters and dark energy.

The above approach is for generic models which can be parameterised, clearly in such an approach all the details of a specific model cannot be included and the conclusions are of a more general nature. I am presently working on applying the methods developed here to a particular class of models, e.g., the quintessence models, to make definitive statements on their viability. Details like including the perturbations in dark energy that cannot be studied in the general approach can be analysed here.

Recently, exact solutions that describe black holes that are bound to a two-brane in a four dimensionsal anti-de Sitter bulk have been constructed. In situations wherein there is a negative cosmological constant on the brane, for large masses, these solutions are precisely the rotating BTZ black holes on the brane and, in fact, describe rotating BTZ black strings in the bulk. In this work, we evaluate the canonical entropy of a massless scalar field (at the Hawking temperature) around the rotating BTZ black string in the brick wall model. We find that, in spite of the additional contribution due to the bulk modes, we are able to recover the Bekenstein-Hawking entropy law for the black string.

Publications:

1. H. K. Jassal, J. S. Bagla and T. Padmanabhan, *Observational constraints on low redshift evolution of dark energy: How consistent are different observations?*, Phys. Rev. D. **72**,*103503 (2005).*

Preprints:

1. H. K. Jassal, J. S. Bagla and T. Padmanabhan, *The vanishing phantom menace,* astro-ph/0601389

Visits to other Institutes:

1. Visit to IUCAA, Pune from March 12 - March 20, 2006

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Dileep Jatkar

Research Summary:

My work in the last year is on deriving the dyon degeneracy formula in four dimensional $N = 4$ supersymmetric compactifications of string theory. We studied a special class of orbifold compactifications, the CHL orbifolds, of heterotic string theory. Using the symmetries of this theory we conjectured the form of the dyon degeneracy formula. We showed that this formula is consistent with the duality symmetries of the CHL orbifolds. We later derived the same formula using the string threshold computation.

Publications:

1. *NS five-brane and tachyon condensation*; Debashis Ghoshal, Dileep P. Jatkar, Maximilian Kreuzer, J.Math.Phys. **46** 062301(2005).

2. *One dimensional M5-brane intersections*; Ansar Fayyazuddin, Tasneem Zehra Husain, Dileep P. Jatkar, Phys.Rev. **D71** 106003(2005).

3. *Dyon spectrum in CHL models*; Dileep P. Jatkar, Ashoke Sen, JHEP **0604** 018 (2006).

Preprints:

1. *Product representation of Dyon partition function in CHL models*; Justin R. David, Dileep P. Jatkar, Ashoke Sen, [hep-th/0602254].

Conference/Workshops Attended:

1. String Workshop at IIT Kanpur, October 3-11 2005.

2. APCTP school on Quantum Field Theory, Pohang, South Korea, February 2-9, 2006.

Visits to other Institutes:

1. Visited Tata Institute, January 3-16, 2006.

2. Visited APCTP, Pohang, South Korea, February 2-9, 2006.

Invited Lectures/Seminars:

1. Lecture at String Workshop, IIT, Kanpur.

2. Seminar at Tata Institute, Mumbai.

3. Gave a set of lectures on $N = 1$ Super Yang-Mills Theories at APCTP, Pohang, South Korea.

Other Activities:

1. Taught a year long course on String Theory.

2. Taught a semester long course on Supersymmetric Yang-Mills Theories.

3. Taught a semseter long course on Quantum Field Theory -I

4. Member of Local Works Committee

5. Convenor of SERC THEP preparatory school held at HRI Nov. 6-25, 2005.

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Pinaki Majumdar

Research Summary:

I have continued working in the general area of disordered interacting electron systems, partly exploring simple models in detail and partly building up towards a comprehensive description of the manganites. I have also started some work on Kondo physics and heavy fermions.

Publications:

1. *Insulator-Metal Phase Diagram of the Optimally Doped Manganites from the Disordered Holstein-Double Exchange Model*: Sanjeev Kumar and P. Majumdar
Phys. Rev. Lett. **96**, 016602 (2006)

2. *The Travelling Cluster Approximation for Strong Correlation Models of Lattice Fermions Coupled to Classical Fields*: Sanjeev Kumar and P. Majumdar
Eur. Phys. J. **B 50**, 571 (2006)

3. *Giant Tunneling Magnetoresistance, Glassiness, and the Energy Landscape at Nanoscale Cluster Coexistence* : Sanjeev Kumar, C. S. Mohapatra and P. Majumdar
Europhys. Lett. **71**, 804 (2005)

4. *Double Exchange Models: Self Consistent Renormalisation*: S. Kumar and P. Majumdar
Eur. Phys. J. **B 46**, 315 (2005)

5. *Transport and Localisation in the Presence of Strong Structural and Spin Disorder*: Sanjeev Kumar and P. Majumdar
Eur. Phys. J. **B 46**, 237 (2005)

Preprints:

1. *Bose-Fermi mixtures in an optical lattice*: K. Sengupta, N. Dupuis and Pinaki Majumdar,cond-mat 0603162.

2. *The Variational Ground State and Finite Temperature Properties of the Kondo Lattice Model with Classical Spins*: Kalpataru Pradhan and Pinaki Majumdar.

3. *Domain Formation and Orbital Ordering Transition in a Doped Jahn-Teller Insulator*: Sanjeev Kumar, Arno P. Kampf and Pinaki Majumdar

Visits to other Institutes:

1. I have been on sabbatical leave from HRI since Feb 2006. The period Feb-March 2006 was spent at the Cavendish Laboratory, University of Cambridge, supported by Trinity College and the EPSRC, UK.

Invited Lectures/Seminars:

The following two seminars were given at Cambridge University:

1. Electron-phonon coupling and disorder in the manganites: towards a theory of the spectral features.

2. Percolative transport and glassiness at nanoscale cluster coexistence.

Other Activities:

Helping in organisation of the annual Science Talent Test, a set of lectures on basic materials theory for BSc/MSc students of Geology at a School organised by Prof. Alok Gupta at Allahabad University, and interviews for the KVPY program.

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Vikas Malik

Research Summary:

I work in the area of compensated and amorphous semiconductors. I work in the limit of high disorder, low interaction strength (low density) between electrons and low temperatures. This regime is called Coulomb or electron glass.

1) Thermodynamics of Coulomb Glass

Collaborators: Dr. Deepak Kumar, J.N.U, India.

The Coulomb glass has been a problem of long standing interest as it involves a very interesting interplay of disorder and Coulomb interactions. The Hamiltonian of the Coulomb glass is basically that of a random field Ising model with long range antiferromagnetic interactions. The key question that arises in this context is whether there is a sharp phase transition to the glassy state. Our motivation in this work is two fold. First we extend the study of question of phase transition by (a) going beyond the mean field approximation (b) taking fully account for of antiferromagnetic Coulomb interactions. For this purpose, we use the replica trick to formulate a non random effective Hamiltonian. Then we use the PHI-derivable approximation in the linked-cluster expansion to calculate the free energy in the random phase approximation (RPA). We find that even in this approximation the phase diagram is qualitatively the same as found in the mean field.

2) Temperature dependence of Density of States

Collaborators: Dr. Deepak Kumar, J.N.U, India.

It was early recognised by Pollak and Srinivasan, that in such systems Coulomb interactions play a crucial role. They showed that the Coulomb interactions create a gap now known as Coulomb gap, in the single particle density of states around the Fermi level. Physically, the gap is attributed to the long range nature of Coulomb interactions which are unscreened in these systems.Our second motivation is to further our understanding of the Coulomb gap, particularly its temperature dependence. Our replica method and thermodynamic approximation is unable to give correct account of the gap as the local correlations around occupied or unoccupied sites have been averaged over. The quantitative derivation of the Coulomb gap is based on the requirement of stability of ground state against one-particle excitations. This treatment applies only at zero temperature.

The other derivations which are based on mean field equations for the occupation number (or magnetization) are not adequate for obtaining the quadratic form of the gap and its temperature dependence. The improvements over the mean field equations are also not transparent in respect to the nature of the correlations that give rise to the Coulomb gap or to the precise role of the long range nature of the interactions. Our analysis makes use of Onsager's cavity field equations for the local magnetization (occupation), but we are able to extract from these considerations some stability requirements on the density of states of the local site energies. Supplementing these requirements with numerical results, we obtain the quadratic gap at zero temperature. Using this result we can extend the result to finite temperature to obtain, for example the rise of DOS at Fermi level, and the variation of the gap with temperature. The role of the long range nature of the interaction is also brought out in a clear manner in the above considerations.

3) Replica Symmetry Breaking

In Spin Glass theory Parisi showed that breaking the replica symmtery was essential to get rid of the unstabilities that were present in the replica symmetric mean field solution and the Onsager Solution. With this in mind I studied the replica symmetry breaking theory of Parisi. I have not been able to make any progress from this angle.

4) Two Site Approximation

The Bethe-Peierls-Weiss approximation which was done in part2 does averaging over the other sites prematurely. I am right now working on the two site approximation, which leads to BPW aproximation. The two site approximation as done by Nakanishi for the spin glass allows more insight into the problem. The analytical solution to Nakanishi's set of equations has not been possible. I will try to do the problem numerically.

Preprints:

1. *Thermodynamics of Coulomb Glass,* Submitted in PRB

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Biswarup Mukhopadhyaya

Research Summary:

The different areas in which investigations have been carried out during the aforesaid peiod are as follows:

- **Little Higgs theories:** A proposal for generating neutrino masses in a Little Higgs scenario, utilising the SU(2) triplet scalars in the particle spectrum, has been formulated. Observable consequences of such a proposal in accelerator experiments have also been investigated (Tao Han, Heather Logan, Biswarup Mukhopadhyaya, R. Srikanth).

- **Supersymmetric theries in colliders** The viability of exploring the properties of a Higgs boson in a split supersynnetric scenario, and the difficulties involvd there, have been studied in detail (Sudhir K. Gupta, Biswarup Mukhopadhyaya, Santosh K. Rai). Also, I have taken part in a worldwide effort to standardise the search strategies for supersymmetry search, in terms of the parameters relevant for variousymmetric theories (the SPA collaboration).

- **Supersymmetry and neutrino mass:** A systematic study has been carried out to link the masses and the bilarge mixing pattern in the neutrino sector to supersymmetric theories where supersymmetry is broken via nonrenormalisable interactions in the hiddedn sector (Biswarup Mukhopadhyaya, Probir Roy, R. Srikanth).

- **doubly charged Higgs search**: The advantage of looking for a doubly charge scalar particle with the help of an associated single photon, which enables one to identify the new particle irrespectively of its decay modes, has been pointed out, in the context of a linear electron-positron collider (Biswarup Mukhopadhyaya and Santosh K. Rai).

Publications:

1. *Bilarge neutrino mixing from supersymmetry with high scale nonrenormalizable interactions* (Biswarup Mukhopadhyaya , Probir Roy, Raghavendra Srikanth) Phys.Rev.D73:035003,2006.

2. *Supersymmetry parameter analysis: SPA convention and project.* (with J.A. Aguilar-Saavedra et al.) Eur.Phys.J.C46:43-60,2006.

3. *Distinguishing split supersymmetry in Higgs signals at the large hadron collider* (Sudhir Kumar Gupta, Biswarup Mukhopadhyaya, Santosh Kumar Rai) Phys.Rev.D73:075006,2006.

4. *Associated single photons as signals for a doubly charged scalar at linear e- e- colliders*(Biswarup Mukhopadhyaya, Santosh Kumar Rai) Phys.Lett.B633:519-525,2006.

5. *Neutrino masses and lepton-number violation in the littlest Higgs scenario* (Tao Han, Heather E. Logan, Biswarup Mukhopadhyaya, Raghavendra Srikanth) Phys.Rev.D72:053007,2005.

6. *Split supersymmetry from anomalous U(1)* (K.S. Babu, Ts. Enkhbat (Oklahoma State U.) , Biswarup Mukhopadhyaya) Nucl.Phys.B720:47-63,2005

Conference/Workshops Organised:

1. Study Group on Extra Dimensions at the LHC– (Harish-Chandra Research insitute, June 7 - 20, 2005).

Visits to other Institutes:

1. Cambridge University, England (as speaker in DAMTP -Cavendish Laboratory joint semninar).

2. Indian Institute of Technology, Kanpur (as invited speaker in conference in celebration of centenary of Albert Einstein's contribution in 1905).

3. Indian Council for Philosophical Research, Delhi (as invited speaker in the seminar of History of Science and Philosophy of Sscience).

4. University of Delhi (as seminar speaker, Physics Department).

5. Banaras Hindu University, Varanasi (as colloquium speaker, Physics Department).

6. Indian Association for the Cultivation of science, Kolkata.

7. Indian Physical Society, Kolkata (to deliver the Annual Special Lecture).

Other Activities at HRI:

1. Course taught in the graduate programme: General Theory of Relativity.
2. Currently supervising three Ph.D. students.
3. Member (later convener), Graduate Committee in Physics, HRI.
4. Member, Transport Committee, HRI.
5. Convener, Faculty Advisory Committee, HRI.
6. Convener, Transport COmmittee, HRI.

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S. Naik

Research Summary:

The Twistor string formulation of $N = 8$ Super gravity

Recently Berkovits and Witten have formulated a twistor string description of $N = 4$ conformal supergravity and super gravity coupled to $N = 4$ super-Yang-Mills theory. However there are inherent problems for the S-matrix formulation of Conformal gravity due to its higher derivative terms. Thus the scattering amplitude for the Einstein super-gravity which happened to be $N = 8$ as maximal supersymmetry is more desirable. Indeed there are several problems for a topological twistor string formulation for $N = 8$ supergravity e la Berkovits and Witten since $N = 8$ superspace cannot be described as a Calabi-Yau space. We address all these issues and try to formualte a string theory to describe the MHV scattering amplitudes for this theory.

Preprints:

1. *The Twistor string formulation of $N = 8$ Super gravity* to appear soon

Conference/Workshops Attended:

1. National String theory Workshop at IIT Kanpur from 9-10-05 to 16-10-05

Visits to other Institutes:

1. IIT, Kanpur

Invited Lectures/Seminars:

1. *The Twistor string formulation of $N = 8$ Super gravity* in String theory Workshop at IIT Kanpur

Courses given:

1. Mathematical Methods Part II from Jan-May 2006

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Andreas Nyffeler

Research Summary:

My field of research is phenomenological particle physics. I work on precision tests of the Standard Model and on new physics models in the TeV region. I am particularly interested in the analysis of the electroweak symmetry breaking sector in the Standard Model and its extensions and in the low-energy structure of the strong interactions. Since joining HRI in February 2006, I have been mostly working on the following topics:

1. Anomalous magnetic moment of the muon

Collaborators: Marc Knecht, Michel Perrottet, CPT-CNRS, Marseille, France

This is some ongoing work on higher order hadronic corrections to the muon $g-2$. Based on methods developed earlier for the evaluation of the pion-pole contribution to hadronic light-by-light scattering, we currently study the contributions from scalar intermediate states. Using QCD short-distance constraints from the operator product expansion on the relevant form factors in large-N_C QCD, in addition to experimental data on the form factors, and with a semi-analytical approach to the resulting two-loop integrals, we try to better assess the model dependence of earlier estimates in the literature. In this way we hope to get a better control of some of the hadronic uncertainties in the Standard Model prediction for the muon $g-2$ which presently make it difficult to interpret the deviation from the experimentally measured value.

2. Little Higgs models with T-parity at future colliders

Collaborators: Biswarup Mukhopadhyaya, Santosh Kumar Rai, R. Srikanth, HRI, India

A few years ago, new physics models called Little Higgs, have been proposed as another solution to the hierarchy problem of the Standard Model. They are situated somehow in between weakly interacting supersymmetric and strongly interacting Technicolor models. In addition to a light Higgs boson, many new particles are predicted in the TeV region, which will be explored by the upcoming LHC collider and, later on, at an International Linear Collider. In particular, if some additional discrete symmetry is invoked, called T-parity, there exists a lightest stable particle which leads to events with missing transverse energy at future colliders and which can serve as a viable dark matter candidate. A thorough understanding of the phenomenology of such Little Higgs models with T-parity is necessary in order to distinguish them from the MSSM with R-parity. We have

started to work out the consequences for searches at the LHC in regions of the parameter space where the signal could be quite different from the MSSM. We are currently also looking at radiative corrections to Standard Model vertices which may be observable at the LHC or the International Linear Collider. As usual, precise measurements of such small deviations test the consistency of physical theories at the quantum level and they might also give hints to the underlying theory (UV completion) since those Little Higgs models only serve as an effective field theory description with a cutoff of about 10 TeV.

Conference/Workshops Attended:

1. 'International Linear Collider Workshop', held at Indian Institute of Science, Bangalore, India, in March 2006.

Other Activities:

1. **Seminars at HRI:** 'The Search for New Physics: An approach with Effective Field Theories', two talks given at HRI in February and March 2006.

2. **Referee's job:** I have refereed one paper submitted to 'Physical Review D'.

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Sudhakar Panda

Research Summary:

We studied the motion of a BPS D3-brane in the NS5-brane ring background. The radion field becomes tachyonic in this geometrical setup. We investigated the potential of this geometrical tachyon in the cosmological scenario for inflation as well as dark energy. We evaluated the spectra of scalar and tensor perturbations generated during tachyon inflation and showed that this model is compatible with recent observations of cosmic microwave background. It is shown that the geometrical tachyon can account for dark energy when the number of NS5-branes is large, provided that inflation is realized by another scalar field. (work with M. Sami and S. Tsujikawa).
We studied inflation arising from the motion of a BPS D3-brane in the background of a stack of k parallel D5-branes. There are two scalar fields in this setup: (i) the radion field R, a real scalar field and (ii) a complex tachyonic scalar field χ living on the world volume of the open string stretched between the D3 and D5 branes. We found that inflation is realized by the potential of the radion field, which satisfies observational constraints coming from the CMB . After the radion becomes of the order of the string length scale l_s, the dynamics is goverend by the potential of the complex scalar field. Since this field has a standard kinetic term, reheating can be successfully realized by the mechanism of tachyonic preheating with spontaneous symmetry breaking. (work with M. Sami, S. Tsujikawa and J. Ward).
Work is in progress in the investigation of CSO-gaugings of N=4 supergravity coupled to vector multiplets to find stable vacuum.

Publications:

1. Panda Sudhakar, Sami M. and Tsujikawa Shinji, *Inflation and dark energy from geometrical tachyons,* Phys. Rev. D73 (2006) 023515.

2. Panda Sudhakar, Sami M., Tsujikawa Shinji and Ward John, *Inflation from D3-brane motion in the background of D5-branes,* Phys. Rev. D73 (2006) 083512.

Preprints:

1. *Inflation and dark energy arising from geometrical tachyons,* S. Panda, M. Sami and S. Tsujikawa,hep-th/0510112.

2. *Inflation from D3-brane motion in the background of D5-branes,* S. Panda, M. Sami. S. Tsujikawa and J. Ward, hep-th/0601037.

Conference/Workshops Attended:

1. 12th Regional Conference on Mathematical Physics, Islamabad, Pakistan.

Visits to other Institutes:

1. University of Groningen, The Netherlands (2005).
2. Harvard University, Boston, USA (2005).
3. Delhi University., Delhi (2005).
4. High Energy Accelerator Center, KEK, Japan (2005-06).
5. Harvard University, USA (2005).
6. Yukawa Insitute, Kyoto, Japan (2005).
7. RIKEN, Tokyo, Japan (2005).

Invited Lectures/Seminars:

1. An update on de Sitter Solution in four dimensional Supergravity; Invited talk in Conference at Islamabad.
2. De Sitter Solution and Gauged Supergravity in d=4; Yukawa Institute, Kyoto, Japan.
3. String Theory and Unification of Interactions; Delhi University, Delhi.
4. De Sitter solution in N=4 supergravity with vector multiplets; Delhi University, Delhi.
5. Group Manifold Reduction, de Sitter solution and Supergravity; RIKEN, Tokyo, Japan.
6. De Sitter solution in Supergravity and String Theory; KEK, Japan.

Academic recognition/Awards:

1. Invited as KEK Fellow for Designated Activities.

Other Activities:

1. Organiser, Cosmology Session in Einstein Legacy meeting, Puri.
2. Member, Security Committee, HRI.

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Tribhuvan Prasad Pareek

Research Summary:

I have been working in the field of mesoscopic spin and charge transport and Quantum computation. The main emphasis was on discovering new physical phenomena and developing appropriate analytical and numerical techniques which allows in-depth quantitative study. We have developed a spin density matrix scattering theory. This theory can can be applied to the case where injector and detector terminals are non-magnetic, i.e., the spins in injector and detector terminals are incoherent, this can be taken into account only via spin density matrix. In our theory this is possible. We have applied this theory to study a novel effect , i.e., **spin orbit induced torque in collinear spin valve** . We have predicted that in collinear spin valve due to spin orbit interaction a torque arises. This torque acting on detector ferromagnet can switch the magnetization and hence can be used as technique to produce read write spintronic device. Further we have shown that spin orbit interaction can produce a pure state from a mixed state. This is shown by calculating Von-Newman entropy. This is particularly important for quantum computation where producing pure state is an important problem. Thus the problem of different fields could be addressed by our approach and hence provides a potential method to study different problems in these fields. This work has been submitted for publication.
We have also proposed a way to measure Rashba spin orbit interaction through all electrical means in a three terminal geometry. This methods relies on conductance measurement and its change as one changes the top gate voltage which inurn changes Rashba interaction. This work will be published soon in IJMPB.

Publications:

1. *Measuring Spin Hall conductance and Rashba spin orbit interaction via electrical measurement in Y shape conductor*. To appear in IJMB

Preprints:

1. *Spin orbit induced torque in collinear spin valve and associated entropy.* Submitted to PRB Rapid communication.

Academic recognition/Awards:

- National science Foundation (NSF) USA have put me as a reviewer for the projects submitted to them. I have reviewed one such project from Havarad university on mesoscopic spin and charge transport.

Other Activities:

I have taught a full semester course on computational methods. Besides this I have given a 5 lecture on mesoscopic physics to visiting summer students. A few of the students worked with me as summer students on aspects of mesoscopic spin and charge transport. Besides these academic activities I have been a member of various committees and accordingly have worked there. Further I have been referee of PRB and PRL and have reviewed many papers for both the journals.

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Santosh Kumar Rai

Research Summary:

In the past one year I have worked on theoretical models of *beyond standard model* physics and have investigated the possible signatures for these models at future collider experiments. I list below a brief summary of the projects I have completed during the last academic year.

(a) Associated single photons as signals for a doubly charged scalar at linear e- e- colliders. (hep-ph/0508290)

Co-authors : Biswarup Mukhopadhyaya

Doubly charged scalars, predicted in many models having exotic Higgs representations, can in general have lepton-number violating (LFV) couplings. In this work we show that by using an associated monoenergetic final state photon seen at a future linear e-e- collider, we can have a clear and distinct signature for a doubly-charged resonance and also determine its mass rather precisely.

(b) Identifying the contribution of Universal Extra Dimensions in the Higgs sector at linear e+ e- colliders. (hep-ph/0509277)

Co-authors : Anindya Datta

We studied the dilepton-dijet signal in the dominant Higgs production channel at a linear e+ e- collider and estimated the effects of Universal Extra Dimension (UED) by a simple analysis of the cross-sections and simple minded ratios of two different final states.

(c) Distinguishing Split Supersymmetry in Higgs signals at the Large Hadron Collider. (hep-ph/0510306)

Co-authors : Sudhir K. Gupta and Biswarup Mukhopadhyaya

In this work we examine the possibility of detecting signals of split supersymmetry in the loop-induced decay $h \to \gamma\gamma$ of the Higgs boson at the Large Hadron Collider, where charginos, as surviving light fermions of the supersymmetric spectrum, can contribute in the loop. We performed a detailed study of uncertainties in various parameters involved in the analysis of the rate, to infer on the possibility of identifying any contribution of split supersymmetry.

(d) UED effects on Higgs signals at LHC. (hep-ph/0510339)

This work is also based on identifying the effects of Universal Extra Dimension (UED), but at the LHC through the Higgs signals. By doing a detailed study of the different uncertainties involved in the measurement of the rates for the process $pp \to h \to \gamma\gamma$ I estimated the extent to which these uncertainties can mask the effects of the contributions coming from UED.

(e) Graviton resonances in $e^+e^- \to \mu^+\mu^-$ at linear colliders with beamstrahlung and ISR. (In writing)

Co-authors : Rohini M. Godbole (CHEP, IISc.) and Sreerup Raychaudhuri (IIT Kanpur).
A common feature at the proposed linear e^+e^- colliders running at center-of-mass energies in the TeV range will be the strong electromagnetic fields associated with the high energy beams. This causes disruption and degradation of the colliding beams due to large amount of radiation of photons. In this work we point out that although these effects are considered as nuisances, one can use them as a search tool for new particle resonances through the $e^+e^- \to \mu^+\mu^-$ channel.

Few other projects which I have started work on, are listed below:

- Use of transverse polarizations at linear e^+e^- colliders to extract new physics signatures. (with Saurabh Rindani (PRL, Ahmedabad))
- Signatures for long lived NLSP at LHC with a right sneutrino LSP. (with Sudhir Gupta and Biswarup Mukhopadhyaya)

Publications:

1. *Associated single photons as signals for a doubly charged scalar at linear e^-e^- colliders.* B. Mukhopadhyaya, S.K. Rai, Phys. Lett. **B633**, 519, 2006.
2. *Distinguishing split supersymmetry in Higgs signals at the large hadron collider.* S.K. Gupta, B. Mukhopadhyaya, S.K. Rai, Phys. Rev. **D73**, 075006, 2006.

Preprints:

1. *Identifying the contributions of universal extra dimensions in the Higgs sector at linear e^+e^- colliders.* A. Datta, S.K. Rai, arXiv:hep-ph/0509277.
2. *UED effects on Higgs signals at LHC.* S.K. Rai, arXiv:hep-ph/0510339.

Conference/Workshops Attended:

1. *Study group on extra dimensions at LHC*, Harish-Chandra Research Institute, Allahabad, India. June 07-20, 2005.

2. IXth *Workshop on High Energy Physics Phenomenology*, WHEPP-9, Institute of Physics, Bhubaneswar, India. January 03-14, 2006.

3. *International Linear Collider Workshop*, LCWS06, Indian Institute of Science, Bangalore, India. March 9-13, 2006.

4. *Monte Carlo tools for Beyond Standard Model Physics*, MC4BSM, Fermilab, USA. March 20-21, 2006.

Visits to other Institutes:

1. Indian Institute of Technology, Kanpur, India. February 07-14, 2006.

2. CHEP, Indian Institute of Science, Bangalore, India. February 27 - March 08, 2006.

3. Fermilab, Batavia, Illinois, USA. March 20-21, 2006.

4. Cornell University, Ithaca, USA. March 27-31, 2006.

Invited Lectures/Seminars:

1. *Monojet Signals for RS model.* HRI, Allahabad, India. June 11, 2005.

2. *Associated single photons as signals for a doubly charged scalar at Linear e^-e^- Colliders.* HRI, Allahabad, India. December 08, 2005.

3. *Identifying new physics contributions in the Higgs sector at linear e^+e^- colliders.* International Linear collider workshop (LCWS06), Indian Institute of Science, Bangalore, India. March 11, 2006.

4. *Associated single photons as signals for a doubly charged scalar at Linear e^-e^- Colliders.* International Linear collider workshop (LCWS06), Indian Institute of Science, Bangalore, India. March 12, 2006.

5. *Associated photons and doubly charged scalar at Linear e^-e^- Colliders.* Cornell University, Ithaca, USA. March 31, 2006.

Other Activities:

1. Joint tutor along with Biswarup Mukhopadhyaya for the course on ”Particle Physics and Standard Model” given by Anindya Datta at the ”Preparatory SERC School” on theoretical High Energy Physics, held in HRI in November, 2005.

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Sumathi Rao

Research Summary:

I continue to work in the area of electronic transport in quantum wires and quantum dots. Our focus in the last year has been to increase our understanding of junctions in quantum wires and also study time dependent or frequency dependent transport.

We have studied a system of an impurity spin coupled to a junction of several quantum wires using a renormalization group scheme. When the wires are disconnected at the origin, there is a range of couplings of the spin to the conduction electrons (called Kondo coupling) for which the systems flows to a 'multi-channel fixed point' for repulsive inter-electron interactions. This is associated with a characteristic temperature dependence of the spin-flip scatterings. If the junction is governed by the Griffiths (symmetrically connected) S-matrix, the Kondo couplings flow to a strong coupling fixed point where its fate is governed by a $(1/\text{Kondo coupling})$ analysis.

We show that novel fixed points (characterized by matrices which specify the splitting of the currents at the junction) can be accessed in a system which contains a junction of three quantum Hall line junctions. For such a junction of fractional quantum Hall edge states, we find that it is possible for both the flower (single droplet) and islands (three droplets) configurations to be stable in an intermediate region, for a range of values of the inter-edge repulsive interactions, in contrast to the Hall bar geometry, where either one is stable. Hence, it should be possible to tune through the intermediate (unstable) fixed point by varying the width of the line junction. A measurement of the tunneling conductance as a function of the gate voltage controlling inter-edge repulsions can give a clear experimental signal of this region.

We study adiabatic charge pumping through a quantum dot placed at the junction of N quantum wires. We explicitly map out the pattern of pumped charge as a function of the time-varying tunneling parameters coupling the wires to the dot and the phase between the two time varying parameters controlling the shape of the dot. We find that the magnitude of pumped charges form an interesting pattern in the parameter space. Large pumped charges are only possible at an optimal value of the asymmetry, which is controlled by a combination of the pumping amplitude and the phase. Most of these features survive as N increases; however, the magnitude of the pumped charge decreases for the same asymmetry parameters.

Publications in refereed journals:

1. *Effects of interaction on an adiabatic quantum electron pump* (with Sourin Das), Phys. Rev. **B**, 165 333 (2005).

2. *Inter-edge interactions and novel fixed points at a junction of quantum Hall line junctions* (with Sourin Das and Diptiman Sen), accepted for publication in Phys. Rev. **B**.

Publications in Conference Proceedings:

1. *'Non-linear sigma model approach to quantum spin chains',* Indian Journal of Physics, June, 2006.

2. *'Women in Physics in India, 2005'* (with Rohini Godbole, Neelima Gupte, Pratibha Jolly and Shobhana Narasimhan), in Proceedings of the second International IUPAP conference on women in physics, Brazil, 2005.

Preprints:

1. *A multi-channel fixed point for a Kondo spin coupled to a junction of Luttinger liquids* (with Ravi Chandra and Diptiman Sen), cond-mat/0510206, submitted to Europhys. Lett.

2. *Adiabatic charge pumping through a dot at the junction of N quantum wires* (with Shamik Banerjee, Anamitra Mukherjee, and Arijit Saha).

3. *Kondo fixed points ...* (with Ravichandra and Diptiman Sen), accepted for publication in Europhys. Lett.

Conference/Workshops Attended:

1. Second International conference on women in physics, Rio de Janeiro, Brazil, 23-25 May, 2005.

2. CMDAYS05, Berhampur University, Gopalpur-on-sea, 29-31 August, 2005.

3. Interactions and dynamics in low dimensional quantum systems, Weizmann Institute, Rehovot, Israel, Jan 3-7, 2006.

4. National Conference on Women, Science and Society, Delhi University, March 9-10, 2006.

Visits to other Institutes:

1. Theoretical condensed matter group, Saha Institute of Nuclear Physics, Kolkatta, April 2005.
2. Centre for Theoretical Studies, Indian Institute of Science, Bangalore, May 2005.
3. Institute for Advanced Studies, Princeton, U.S.A May 20-25 2005.
4. Harvard University, Boston, U.S.A, June 1-15, 2005.
5. Weizmann Institute, Rehovot, Israel, Dec 20 2005 - Jan 10, 2006.

Invited Lectures/Seminars:

1. 'Transport through quantum wires and dots', Saha Institute, Kolkatta.
2. 'Effect of interactions on an adiabatic quantum pump', Centre for Theoretical Studies, Indian Institute of Science, Bangalore.
3. 'Correlation effects on transport through junctions of quantum wires', Dept. of Physics, Princeton University, May 2005.
4. 'Correlation effects on transport through junctions of quantum wires', Dept. of Physics, Harvard University, June 2005.
5. 'Non-linear sigma model approach to quantum spin chains', Berhampur University, Gopalpur-on-sea, 29 August 2005.
6. 'Correlation effects on transport through junctions of quantum wires', Weizmann Institute, Jan 2, 2006.
7. 'There's room at the bottom', HRI Local annual meeting, Feb 6-8, 2006.
8. 'Women in physics, 2005', Delhi University, March 2006.

Other Activities:

1. Taught condensed matter physics, August 2005-Dec 2005
2. Taught advanced quantum mechanics, Jan 2006-May 2006
3. Organised 'Local Annual meeting', Feb 6-8, 2006.

4. Administrative Duties

   (a) Convenor, Local works committee
   (b) Convenor, XI plan committee
   (c) Member, Budget committee
   (d) Member, Faculty advisory committee
   (e) Convenor, Women's grievance cell

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V. Ravindran

Research Summary:

Higher order QCD corrections to inclusive processes not only reduce the theoretical uncertainties but also reveal interesting structures in perturbation theory [1,2]. We have studied the soft part of the inclusive processes such as Drell-Yan, Higgs production beyond two loop level in order to understand these structures. We extract soft distribution functions for these processes using mass factorisation theorem and the perturbative results that are known upto three loop level. We find that they are maximally non-abelien. We show that these functions satisfy Sudakov type integro differential equations. The formal solutions to such equations and also to the mass factorisation kernel upto four loop level are presented. Using the soft distribution function extracted from Drell-Yan production, we show how the soft plus virtual cross section for the Higgs production can be obtained. We determine the threshold resummation exponents upto three loop using the soft distribution function. Using these resummed results, we have computed threshold enhanced QCD corrections to inclusive processes such as Deep inelastic scattering, Drell-Yan process and Higgs productions through gluon fusion and bottom quark annihilation processes. We show how these higher order threshold QCD corrections improve the theoretical predictions for the Higgs production through gluon fusion at hadron colliders.

Higher order QCD corrections play important role in physics beyond standard model [3,4,5]. In this context, we have studied the impact of these corrections in four-fermi theories and models with extra-dimensions that are of phenomenological interest in the Large Hadron Collider(LHC). We consider lepton pair production at a hadron collider in a class of effective theories with the relevant operators being four-fermion contact interaction. Despite the nonrenormalizable nature of the interaction, we explicitly demonstrate that calculating QCD corrections is both possible and meaningful. Calculating the corrections for various differential distributions, we show that these can be substantial and significantly different from those within the SM. Furthermore, the corrections have a very distinctive flavour dependence. And finally, the scale dependence of the cross sections are greatly reduced once the NLO corrections are taken into account. The dilepton production process at hadron colliders in the Randall-Sundrum (RS) model is studied at next-to-leading order in QCD. The NLO-QCD corrections have been computed for the virtual graviton exchange process in the RS model, in addition to the usual gamma, Z-mediated processes of standard Drell-Yan. K-factors for the cross-sections at the LHC and Tevatron for differential in the invariant mass, Q, and the rapidity, Y, of the lepton pair are presented. We find the K-factors are

large over substantial regions of the phase space. In TeV scale gravity models, for dilepton production at hadron colliders, we present the NLO-QCD corrections for the double differential cross section in the invariant mass and scattering angle. For both ADD and RS models, the quantitative impact of QCD corrections for extra dimension searches at LHC and Tevatron are investigated. We present the K-factors for both ADD and RS models at LHC and Tevatron. Inclusion of QCD corrections to NLO stabilises the cross section with respect to scale variations.

Publications:

1. V. Ravindran, *"Higher-order threshold effects to inclusive processes in QCD,"* arXiv:hep-ph/0603041, To appear in Nuclear Physics **B**.

2. V. Ravindran, *"On Sudakov and soft resummations in QCD,"* Nucl. Phys. B **746**, 58 (2006) [arXiv:hep-ph/0512249].

3. D. Choudhury, S. Majhi and V. Ravindran, *"NLO corrections to lepton pair production beyond the standard model at hadron colliders,"* JHEP **0601**, 027 (2006) [arXiv:hep-ph/0509057].

4. P. Mathews and V. Ravindran, *"Angular distribution of Drell-Yan process at hadron colliders to NLO-QCD in models of TeV scale gravity,"* [arXiv:hep-ph/0507250], To appear in Nuclear Physics **B**.

5. P. Mathews, V. Ravindran and K. Sridhar, *"NLO-QCD corrections to dilepton production in the Randall-Sundrum model,"* JHEP **0510**, 031 (2005) [arXiv:hep-ph/0506158].

Preprints:

1. S. Alekhin *et al.*, *"HERA and the LHC - A workshop on the implications of HERA for LHC physics: Proceedings Part B,"* arXiv:hep-ph/0601013.

2. S. Alekhin *et al.*, *"HERA and the LHC - A workshop on the implications of HERA for LHC physics: Proceedings Part A,"* arXiv:hep-ph/0601012.

3. M. Dittmar *et al.*, *"Parton distributions: Summary report for the HERA - LHC workshop,"* arXiv:hep-ph/0511119.

Conference/Workshops Attended:

1. 7th International Symposium on Radiative Corrections, APPLICATION OF QUANTUM FIELD THEORY TO PHENOMENOLOGY, Shonan Village, Japan, October 2-7, 2005

2. IX WORKSHOP ON HIGH ENERGY PHYSICS PHENOMENOLOGY, Institute of Physics, Bhubaneswar, 03 January - 14 January, 2006

Visits to other Institutes:

1. Theory group, Tata Institute of Fundamental Research from 27th March to April 2nd.
2. TPSC visit to Theory group, Physical Research Laboratory, Ahmedabad from 12th to 16th September 2005.

Invited Lectures/Seminars:

1. Seminar on ”Importance of QCD at TeV Colliders” in the theory group in Tata Institute of Fundamental Research.
2. Colloquium on ”QCD results for Higgs Searches” in Tata Institute of Fundamental Research.
3. Seminar on ”Higgs production at LHC” in the theory group in Physical Research Laboratory.

Other Activities:

1. Coordinator of QCD working group in 9th Workshop on High Energy Physics Phenomenology, Institute of Physics, Bhubaneswar.
2. Served as a member of Foreign Travel Committee.
3. Served as a member of Library Committee.

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Arnab Kumar Ray

Research Summary:

The following is the summary of the research work done since the submission of the last annual report in 2005.

- For the circular hydraulic jump, an equation of motion for a time-dependent perturbation exhibits the properties of an acoustic white hole, and in conformity with this, the perturbation as a travelling wave suggests that a wave moving upstream from highly sub-critical regions, destabilises the flow in the vicinity of the jump. Surface tension has also been shown to effect an abrupt transition in the flow.

- In the thin accretion disc, viscosity has been introduced as a small perturbative effect about the inviscid solution. Imposing a linearised time-dependent perturbation on the steady solutions of this "quasi-viscous" and thin accretion disc leads to the development of an instability on large length scales. Treating the perturbation as a standing wave, constrained at two separate spatial points, shows that the perturbation has a growth behaviour in time. Treating the perturbation as a travelling wave shows that its amplitude and its energy flux, will both exponentially diverge on large length scales of the thin disc. A transformation of the velocity field carried out to study the long-time behaviour of the disc on large length scales, indicates a formal closeness with Schrödinger's equation with, however, a repulsive potential. The same perturbative analysis also reveals that for the inviscid disc, there is a very close correspondence between the equation for the propagation of the perturbation and the metric of an acoustic black hole. Compatible with the transport of angular momentum to the outer regions of the disc, a viscosity-limited length scale is further defined for the spatial extent of the inward rotational drift of matter.

- For inviscid rotational accretion flows, both isothermal and polytropic, a simple dynamical systems analysis of the critical points has been found to indicate very accurately the nature of those points, for any general pseudo-potential by which the flow is driven on to a Schwarzschild black hole. Not only are the physical properties of the stationary flow solutions (especially the critical solutions) understood better this way, it also allows for a more complete classification of the critical points for a wide range of flow parameters. These results have been compared with those established through numerical integration of the differential equations governing the flow, and

this dynamical systems study can be claimed to be a relatively simple alternative mathematical way to study accretion problems of this nature. Furthermore, a time-dependent perturbative analysis reveals that the form of the perturbation equation, for both isothermal and polytropic flows, is free of the choice of any particular pseudo-potential. Under a generically true asymptotic condition, the inviscid flow has been argued to be stable for any case. The perturbation equation has also served the dual purpose of enabling an understanding of the acoustic geometry for inviscid and rotational flows.

Publication(s):

1. S. B. Singha, J. K. Bhattacharjee and A. K. Ray, *Hydraulic jump in one-dimensional flow*, European Physical Journal B, 48, 417, 2005.

Preprint(s):

1. Arnab K. Ray and J. K. Bhattacharjee, *A dynamical systems approach to a thin accretion disc and its time-dependent behaviour on large length scales*, 2005.

2. Arnab K. Ray and J. K. Bhattacharjee, *A time-dependent study of the circular hydraulic jump using the shallow water approach*, 2006.

3. Soumini Chaudhury, Arnab K. Ray and Tapas K. Das, *A dynamical systems approach to axisymmetric astrophysical accretion*, 2006.

Visits to other Institutes:

1. Inter–University Centre for Astronomy and Astrophysics, Pune, India, November 3 to 10, 2005.

2. Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India, November 11 to 20, 2005.

3. Raman Research Institute, Bangalore, India, November 21 to 28, 2005.

4. School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India, February 19 to 28, 2006.

5. Inter–University Centre for Astronomy and Astrophysics, Pune, India, June 15 to 26, 2006.

Invited Lectures/Seminars:

1. *A time-dependent perturbative study of the shallow water hydraulic jump* at the Inter–University Centre for Astronomy and Astrophysics, Pune, India, on November 8, 2005.

2. *A time-dependent perturbative study of the shallow water hydraulic jump* at the Department of Physics, Indian Institute of Science, Bangalore, India, on November 21, 2005.

3. *A time-dependent perturbative study of the shallow water hydraulic jump* at Raman Research Institute, Bangalore, India, on November 22, 2005.

4. *A time-dependent perturbative study of the shallow water hydraulic jump* at Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India, on November 28, 2005.

5. *A time-dependent perturbative study of the shallow water hydraulic jump* at the Department of Physics, Indian Institute of Technology, Chennai, India, on November 30, 2005.

6. *A time-dependent perturbative study of the shallow water hydraulic jump* at the Centre for Theoretical Studies, Indian Institute of Technology, Kharagpur, India, on December 15, 2005.

7. *A time-dependent perturbative study of the shallow water hydraulic jump* at the S. N. Bose National Centre for Basic Sciences, Kolkata, India, on December 23, 2005.

8. *A time-dependent perturbative study of the shallow water hydraulic jump* at the Theory Group, Saha Institute of Nuclear Physics, Kolkata, India, on December 26, 2005.

9. *A time-dependent perturbative study of the shallow water hydraulic jump* at the School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India, on February 22, 2006.

10. *A time-dependent perturbative study of the shallow water hydraulic jump* at the Department of Physics, Delhi University, New Delhi, India, on February 27, 2006.

Other Activities:

1. Presented an astrophysics seminar at Harish–Chandra Research Institute on the topic of *Critical solutions and the large scale properties of an accretion disc*, on January 18, 2006.

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Amitava Raychaudhuri

Research Summary:

INO: In its first phase, the India-based Neutrino Observatory (INO) will investigate neutrino properties through atmospheric neutrino oscillations. A GEANT-based simulation of the detector has been used to examine the capabilities and reach of this experiment. These studies will be useful for future planning and optimisation of the detector design. This work is included in the INO interim report which will be circulated among experts for their views.

Beta beam: Beta beams are being investigated as possible future sources for intense ν beams. Work was done to study the reach of long baseline neutrino oscillation experiments with beta beams.

Extra dimensions: Extra dimensional models are phenomenologically interesting. Orbifold-based models have been looked into with flavour mixing in mind. Universal extra dimensional models are also under examination.

Publications:

1. *'Exploration prospects of a long baseline Beta Beam neutrino experiment with an iron calorimeter detector'*, Sanjib Kumar Agarwalla, Amitava Raychaudhuri and Abhijit Samanta, Phys. Lett. **B629,** 33–40 (2005).

2. *'Remarks on flavour mixings from orbifold compactification'*, Gautam Bhattacharyya and Amitava Raychaudhuri, J. Phys. G: Nucl. and Part. Phys., **32** B1-B5 (2006).

Conference/Workshops Attended:

1. INO Collaboration Meeting, Mumbai

2. INO Collaboration Meeting, Kolkata

Invited Lectures/Seminars:

1. Physics Department, Delhi University (Colloquium)

2. Physics Department, Allahabad University

3. Unversity of Maryland, USA

4. University of Delaware, USA

5. College of William and Mary, USA
6. Thomas Jefferson Laboratory, USA (Colloquium)
7. Brookhaven National Laboratory, USA
8. SERC School in Nuclear Physics, VECC, Kolkata

Academic recognition/Awards:

- Meghnad Saha Memorial Gold Medal (2005),The Asiatic Society, Kolkata
- International Alumnus of the Year (2005), University of Maryland Alumni Association, Maryland, USA.

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Ashoke Sen

Research summary

My work during last year has been on various aspects of black holes in string theory. The topics can be divided into three main areas.

Entropy function: I showed that in theories of gravity coupled to other matter fields with generally covariant higher derivative corrections, the near horizon field configuration of an extremal black hole is obtained by extremizing an 'entropy function'. The entropy function is a function of the parameters characterizing the near horizon geometry of the black hole and there is a well defined algorithm for constructing this function from the lagrangian density of the theory. Furthermore the entropy itself is given by the value of the entropy function at its extremum. This led to a proof of the 'attractor mechanism' in a general higher derivative theory of gravity without invoking supersymmetry. In particular the results show that in a generic situation where the entropy function has no flat directions the near horizon field configuration is determined completely by extremizing the entropy function and hence cannot depend on the asymptotic values of the scalar fields of the theory. On the other hand if the entropy function has flat directions then the near horizon field configuration is not completely determined by extremizing the entropy function and could have some dependence on the asymptotic values of the scalar fields. But the entropy is still independent of the asymptotic data. Although initial studies focussed on spherically symmetric black holes, in collaboration with B. Sahoo I generalized this approach to study rotating black holes in three dimensions.

Dyon spectrum in CHL models: In collaboration with D. Jatkar and J. David I computed the degeneracy of dyons in a class of string theories with $\mathcal{N} = 4$ supersymmetry in four dimensions. We checked the duality invariance of the spectrum as well as its agreement with black hole entropy to first non-leading order in an expansion in powers of inverse charges. Knowledge of the exact degeneracy will be useful in pushing the comparison between black hole entropy and statistical entropy to higher orders.

Black holes and elementary strings: I continued my earlier investigation of the precise nature of the correspondence between black holes and elementary strings. In particular I was able to extend the investigation of this correspondence to black holes in higher dimensions.

Publications :

1. A. Sen, *Black holes and the spectrum of half-BPS states in N = 4 supersymmetric string theory,*

Adv. Theor. Math. Phys. **9**, 527 (2005) [arXiv:hep-th/0504005].

2. A. Sen, *Stretching the horizon of a higher dimensional small black hole,* JHEP **0507**, 073 (2005) [arXiv:hep-th/0505122].
3. A. Sen, *Black hole entropy function and the attractor mechanism in higher derivative gravity,* JHEP **0509**, 038 (2005) [arXiv:hep-th/0506177].
4. A. Sen, *Entropy function for heterotic black holes,* JHEP **0603**, 008 (2006) [arXiv:hep-th/0508042].
5. D. P. Jatkar and A. Sen, *Dyon spectrum in CHL models,* JHEP **0604**, 018 (2006) [arXiv:hep-th/0510147].
6. B. Sahoo and A. Sen, *BTZ black hole with Chern-Simons and higher derivative terms,* [arXiv:hep-th/0601228] (to appear in JHEP).
7. J. R. David, D. P. Jatkar and A. Sen, *Product representation of dyon partition function in CHL models,* arXiv:hep-th/0602254 (to appear in JHEP).

Preprints :

1. B. Sahoo and A. Sen, Higher derivative corrections to non-supersymmetric extremal black holes in N = 2 supergravity, arXiv:hep-th/0603149 (submitted for publication).

Invited Lectures/Seminars :

1. **Invited talks given at conferences and schools**
   (a) Summer School on Strings, Gravity and Cosmology, Perimeter Institute, June 20 - July 8, 2005, Waterloo, Ontario, Canada
   (b) Strings 05 Conference, Fields Institute, July 11-16, 2005, Toronto, Canada
   (c) Workshop On Einstein's Legacy In The New Millennium, 15-22 Dec 2005, Tohsali Sands, Puri, India
   (d) 23rd Winter School In Theoretical Physics: String Theory: Symmetries And Dynamics, 28 Dec 2005 - 6 Jan 2006, Jerusalem, Israel
   (e) 12th Regional Conference on Mathematical Physics, 27 Mar - 1 Apr 2006, Islamabad, Pakistan

2. **Special lectures**

   (a) Dirac lecture, June 20 2005, DAMTP, Cambridge University, UK

   (b) Einstein Colloquium, December 27 2005, Weizmann Institute, Israel.

Academic recognition/Awards :

- H. K. Firodia award, 2005

Other Activities :

- **Courses given**

  1. Quantum field theory I: Spring 2005
  2. Classical mechanics: Fall 2005
  3. Statistical mechanics: Spring 2006

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Prasenjit Sen

Research Summary:

My main research activities during this period has been focused on understanding physical properties of some nanoscale materials. The first systems I studied is an atomically thin wire of sodium atoms. One-dimensional (1D) metallic wires have attracted a lot of attention in the recent past, both because they have enormous scope for applications in nano-electronics, and because they can show properties that challenge our understanding of the physics of low-dimensional systems.

In fact, an argument by Sir Rudolf Peierls says that a uniform atomic wire with partially filled electronic bands can never be stable in 1D, and will always distort longitudinally to an insulating state, now called a Peierls insulator. Although experiments can produce only finite wires that are atomically thin, theorists have calculated properties of infinite 1D wires of various metals with first-principles methods. Contrary to Peierls's original argument, all metallic systems studied so far are found to have a stable metallic phase over a certain range of interatomic distances. So far there was no understanding as to why this is so. In my recent work, studying properties 1D sodium wire within density functional theory, I found the same behavior. I then explained the absence of a Peierls instability in terms of the electron-phonon coupling strength in the system. At small interatomic distances, the electron-phonon coupling in the system is rather small, and this is responsible for absence of a peierls instability. At larger interatomic distances, the electron-phonon coupling in the system increases greatly. This leads to a Peierls insulating phase just before the wire breaks because of stretching. The Peierls instability in the system is also found to be rather weak in the sense that the energy gain due to dimerization of successive atoms is very small.

Another problem I am currently working on is on small sodium clusters. Atomic clusters also have extremely useful applications, and are also a class of systems which allows us a way to systematically study how physical properties evolve as we go from the atomic scale to the bulk scale. Various researchers have studied properties of pure sodium clusters for some time now. Many of their properties, particularly relative stabilities of clusters of different sizes, can be understood in terms of either electronic shell closure, or geometric shell closure. We are studying mixed sodium-transition metal clusters. The motivation is to understand to what extent the electronic shell model is valid in these mixed bi-metallic clusters, and also to search for magnetic clusters, since unfilled d-shells in the transition metals are expected to give rise to magnetic moments. This is following similar

studies on Al-TM and Au-TM clusters which have produced extremely encouraging results.

Publications:

1. *Structural studies of Phosphorous induced dimers on Si(001)*, P. Sen, B. C. Gupta and I. P. Batra, Phys Rev B 73, 085319 (2006).

Preprints:

1. *Peierls Instability and Electron-Phonon Coupling in a One-dimensional Sodium Wire*, P. Sen.

Conference/Workshops Attended:

1. IPS 2005, University of Illinois at Chicago, Chicago IL, USA, July 2005.
2. Summer School on "First Principles Calculations for Condensed Matter and Nanoscience" at the International Center for Materials Research, University of California at Santa Barbara, Santa Barbara CA, USA in Aug-Sep 2005.
3. Indo-European Thematic Meeting on Computational Material Science at IISc Bangalore in February 2006.

Visits to other Institutes:

1. Visited University of Illinois at Chicago, Chicago IL, in July-Aug 2005.

Invited Lectures/Seminars:

1. Delivered a talk titled *"P on Si(001): Some First-Principles Results"* at the India Physics Symposium at the Univ. of Illinois at Chicago, Chicago IL USA, in July 2005.

Other Activities:

1. I advised three VSP students, Soumen Samanta (IIT-Kanpur), Prerna Sharma (St. Stephens College, Delhi), and Deepti Pachauri (IIT-Delhi) in the summer of 2005.
2. I taught Mathematical Methods I in Aug 2005 semester.

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L. Sriramkumar

Research Summary:

During the last year, my research work was primarily focused on investigating the following issues in inflationary cosmology:

1. Planck scale corrections to the primordial spectrum
2. Scale-free spectrum from non-vacuum initial states
3. Amplification of curvature perturbations at super-Hubble scales
4. k-inflation in higher dimensions

I have been studying the issues 2–4 listed above along with my graduate student Rajeev Kumar Jain. Brief description of the problems we have been investigating in these contexts can be found in his report. In what follows, I shall briefly describe the work I have been involved in on issue 1.

Over the last few years, there has been a large amount of effort in the literature on understanding the effects of Planck scale physics on the inflationary perturbation spectrum and the resulting signatures on the cosmic microwave background. In the absence of a viable quantum theory of gravity, the Planck scale effects have often been studied using phenomenological models constructed by hand—models which are supposed to contain one or more features of the actual theory. The different high energy models that have been considered in the literature modify either the dynamics or the initial conditions of the canonical scalar field. Importantly, most of the high energy models that have been considered in this context violate local Lorentz invariance. However, certain astrophysical observations seem to indicate that Lorentz invariance may be preserved to very high energies. In such a situation, it becomes imperative to consider models that preserve local Lorentz invariance even as they contain a fundamental scale. One such high energy model is the approach due to path integral duality. We are presently using this approach to study the Planck scale corrections to the primordial spectrum.

Publications:

1. L. Sriramkumar and T. Padmanabhan, *Initial state of matter fields and trans-Planckian physics: Can CMB observations disentangle the two?*, Phys. Rev. D **71**, 103512 (2005).

Conference/Workshops Attended:

1. *International Conference on 'Einstein's Legacy in the New Millennium'*, Toshali Sands, Puri, December 15–22, 2005.

2. *School on Cosmology and the Very Early Universe*, Inter-University Centre for Astronomy and Astrophysics, Pune, December 25–30, 2005.

Visits to other Institutes:

1. *Physical Research Laboratory*, Ahmedabad, February 8–10, 2006.

2. *Department of Physics, Delhi University*, Delhi, February 22–24, 2006.

Invited Lectures/Seminars:

1. *Does the primordial spectrum probe Planck scale physics?*, Seminar at Physical Research Laboratory, Ahmedabad, February 8, 2006.

2. Guest Lecturer for Prof. Urjit Yagnik's course on *Cosmology for Particle Physicists* at the SERC Main School in Theoretical High Energy Physics, Physical Research Laboratory, Ahmedabad, February 11–20, 2006.

Other Activities:

1. Guided the following two HRI graduate students on their project towards the end of their coursework:
   • Rajeev Kumar Jain, *The origin and evolution of density perturbations*
   • Nishikanta Khandai, *The physics of CMBR anisotropies*

2. Guided the following two integrated M.Sc. Physics students on a project under the Visiting Students' Program: Himanshu Sharma and Deepak Khurana. Both these students were from Indian Institute of Technology, Kharagpur.

3. Was involved in conducting (the Physics part of) the HRI Science Talent Test 2005.

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Sanjib Kumar Agarwalla

Research Summary:

I have been working mostly on the issues related with neutrino mixing and the precision study of neutrino oscillation parameters. I am also working on some INO (India based Neutrino Observatory) related topics. Right now I am working on the following projects:

1) Signals of new physics with beta beam in R-parity violating supersymmetry

Collaborators : Subhendu Rakshit, University of Dortmund, Zylon, Germany; Amitava Raychaudhuri, Harish-Chandra Research Institute, Allahabad, India.

We investigate the possibility of observing some signals of new physics coming from the r-parity violating (RPV) super-symmetric (SUSY) interactions with the beta beam neutrino source. Tau leptons can be produced in the final stage from an initial pure electron neutrino beta beam even in the absence of neutrino oscillation, with the help of some lepton number violating trilinear couplings that arise in the RPV SUSY framework. A near detector placed with in 1 Km from the β-beam storage ring offers an unique opportunity to observe the signal of muons which appears inside the detector due to the instant leptonic decay of these tau leptons into muons. Thus a near detector with the β-beam source creates an environment to improve the existing bounds on these non-standard couplings. We examine how the signatures of new physics varies with the collimation of the initial beam and with the distance of the detector from the storage ring. We have shown that the geometry of the storage ring and the shape and size of the detector play a very crucial role in optimizing the signal of new physics and to put stringent bounds on these RPV couplings.

2) Effect of supersymmetry in θ_{13} measurement and constraining $\not{R}$-couplings in long baseline beta beam experiment

Collaborators : Rathin Adhikari, Jagadis Bose National Science Talent Search, Kolkata, India; Amitava Raychaudhuri, Harish-Chandra Research Institute, Allahabad, India.

Long baseline precision oscillation experiments may well emerge as test beds for neutrino interactions. R-parity violating supersymmetry induces flavour diagonal (FDNC) and flavour changing (FCNC) neutral current interactions which, in addition to electroweak effects, may be probed. We discuss effects of such FCNC and FDNC in extracting θ_{13} by a long baseline experiment using a β-beam,

with the source at CERN and the detector at the proposed India-based Neutrino Observatory (INO). Unless the upper bounds on $\not{R}$ couplings, particularly λ', become significantly more stringent, these interctions, if present, may preclude any improvement on the present bound $\theta_{13} < 12^0$. On the other hand, it might be possible to give stringent lower bounds on θ_{13}. We show that through such an experiment, particularly in the inverted hierarchy scenario and also in some cases in the normal hierarchy, there is scope to see a clear signal of non-standard FCNC interactions. In favourable cases, it may be possible to set lower and upper bounds on λ' couplings in the normal hierarchy scenario whereas for an inverted hierarchy only lower bound on such couplings may be obtained. FCNC and FDNC interctions due to λ type $\not{R}$ couplings are unimportant. A few remarks are made about other models. CP-violation has not been included here.

Publications:

1. S. K. Agarwalla, A. Raychaudhuri and A. Samanta, *"Exploration prospects of a long baseline beta beam neutrino experiment with an iron calorimeter detector,"* Phys. Lett. B **629**, 33 (2005) [arXiv:hep-ph/0505015].

Conference/Workshops Attended:

1. Satellite neutrino meeting Mumbai, August 1-2, 2005, preceeding the International Cosmic Ray Conference, ICRC2005, Pune, Aug 2005.

2. Ninth Workshop on High Energy Physics Phenomenology (WHEPP-9), Institute of Physics, Bhubaneswar, January 3-14, 2006.

3. . XXI SERC Main School in Theoretical High Energy Physics, Physical Research Laboratory, Ahmedabad, 11th Feb to 5th Mar.

Invited Lectures/Seminars:

1. "The novel aspects of a long baseline Beta Beam experiment with INO", at Satellite neutrino meeting Mumbai, August 1-2, 2005, preceeding the International Cosmic Ray Conference, ICRC2005, Pune, Aug 2005.

2. "Scoping study: Beta Beam and INO", at INO simulation meeting HRI Allahabad, October 24-26, 2005.

3. "Physics reach of CERN – INO baseline with Beta Beam", at WHEPP-9, Institute of Physics, Bhubaneswar, January, 2006.

Other Activities:

1. **Pheno Lunch Review Talks:** " Probing the earth's interior with the low energy neutrino astronomy detector" hep-ph/0509136.

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Nabamita Banerjee

Research Summary:

My research interest is in Conformal Field Theory, Noncritical String Theory. Currently I am working on branes in pp wave backgrounds.

Conference/Workshops Attended:

1. National String Theory Workshop 2005: IIT, Kanpur, October 2005.
2. Einstein's Legacy in New Millennium, Puri, December 2005.
3. 23rd Winter School in Theoretical Physics, Jerusalem, December 2005 - January 2006.

Other Activities:

1. Teaching Assistant, GTR Course, August to December 2005.

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Suvankar Dutta

Research Summary:

I am mainly working on ADS/CFT correspondence. In my research I plan to apply this correspondence to QCD. QCD above the deconfining temperature is strongly interacting plasma of quarks and gluons in the coulomb phase, and seems to be described by a strongly interacting conformal field theory. One of my aim is to apply the ADS/CFT correspondence to obtain new results about the strongly coupled QCD side.

In my last problem I worked on a related problem. One can calculate the entropy of asymptotically AdS not-extremal black holes by Euclidean approach after making a background subtraction. For such black holes one can consider the effect of higher derivative corrections to the action from terms like Gauss-Bonnet term, $(RiemannTensor)^2$ term or $(WeylTensor)^4$ term, and euclidian approach is able to calculate the correction to BH entropy due to the presence of these terms. At the same time one can also apply Wald's formula for the entropy for higher derivative terms. I have calculated the entropy using both approaches for the action containing above higher derivative corrections. And I have got the same results in both approaches. I have found out the relation between these two approaches of calculating entropy.

Preprints:

1. *On Euclidean and Noetheran Entropies in Ads space*. (in preparation)

Conference/Workshops Attended:

1. National String Theory Workshop 2005: IIT, Kanpur, October 2005.
2. Einstein's Legacy in New Millennium, Puri, December 2005.
3. 23rd Winter School in Theoretical Physics, Jerusalem, December 2005 - January 2006.

Invited Lectures/Seminars:

1. Saha Institute of Nuclear Physics, April, 2006 (Seminar)

Other Activities:

1. Teaching Assistant, Particle Physics Course August to December 2005.

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Pomita Ghoshal

Research Summary:

In the last year, I have tried to understand further the sensitivity to the neutrino mass hierarchy in future atmospheric neutrino experiments. Specifically, we have been working on a numerical study of the proposed future experiments with an iron calorimeter detector (INO) and a megaton water Cerenkov detector (Hyper Kamiokande).

This study involves an analysis of earth matter effect contributions and other possible contributions to this sensitivity at the probability level, as well as a study of the actual sensitivity in the event rates. We are attempting to improve our analysis by including more realistic estimates of the possible statistical and systematic errors. We try to take into account the resolution functions which smear the event distributions, thus affecting the sensitivity, as well as parameter uncertainties and correlations which may further reduce it. As part of this ongoing work, we aim to refine the methods of error analysis earlier used by us.

Publications:

1. R. Gandhi, P. Ghoshal, S. Goswami, P.Mehta, S. Uma Sankar, *Earth Matter Effects at Very Long Baselines and the Neutrino Mass Hierarchy* , Phys. Rev. D 73, 053001 Resolving the neutrino mass hierarchy from atmospheric neutrinos

Preprints:

1. R. Gandhi, P. Ghoshal, S. Goswami, P.Mehta, S. Uma Sankar, *Probing the neutrino mass hierarchy via atmospheric $\nu_\mu + \bar{\nu_\mu}$ survival rates in megaton water Cerenkov detectors*, hep-ph/0506145

Conference/Workshops Attended:

1. Workshop on Neutrinoless Double Beta Decay (NDBD), University of Lucknow, Lucknow (4th - 5th November, 2005)

2. Workshop on High Energy Physics Phenomenology (WHEPP-9), Institute of Physics, Bhubaneswar (3rd - 14th January, 2006)

Invited Lectures/Seminars:

1. Talk given on *"The neutrino mass hierarchy from the atmospheric neutrino signal in a megaton water Cerenkov detector"*, NDBD, University of Lucknow, Lucknow (4th - 5th November, 2005)

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Sudhir Kumar Gupta

Research Summary

In the earlier phase of the past academic year I was focusing on distingushing the Split Supersymmtery signals with the Minimal Supersymmetric Standard Model signals. In this context we (myself, Biswarup Mukhopadhyaya and Santosh K Rai) studied Diphoton production through Higgs decay at the Large Hadron Collider. Finally we have been able to show that it is difficult to distinguish between the two due to large QCD uncertainty in Higgs production.

Since November we are trying to explore the possibility of having right handed sneutrino dark matter in the Supergravity inspired scenarios. We have identified the relevant parameter space and are currently looking for some distinctive collider signals using event generators.

Publications:

1. *Distinguishing split supersymmetry in Higgs signals at the Large Hadron Collider* (Sudhir K Gupta, Biswarup Mukhopadhyaya and Santosh K Rai), Phys.Rev.D73:075006,2006 (hep-ph/0510306).

Conference/Workshops Attended:

1. Workshop on Extra Dimensions at Colliders, HRI, Allahabad, June'05.
2. Workshop in High Energy Physics Phenomenology (WHEPP'06), IOP, Bhubneshwar, Jan'06.
3. International Conference in Computing in High Energy and Nuclear Physics (ICHEP'06), TIFR, Mumbai, Feb'06.
4. International Linear Collider Workshop (ILCWS'06), IISC, Banglore, March'06.

Invited Lectures/Seminars:

1. R-parity Violation in split supersymmetry, HRI, Allahabad, May'05.
2. Looking for Split Supersymmetry in Higgs Signals, IISC, Banglore, March'06.

Other Activities:

1. Prepared a report on Extra Dimensions in Randal-Sundaram Scenario for "Extra Dimesion at LHC Workshop", June'05.
2. Gave a talk in Pheno Lunch on Neutrinos in Warped Extra Dimension Aug'05.

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Raghavendra Srikanth H.

Research Summary:

I have worked on the model building aspects of neutrino masses and mixing. Neutrinos are elementary particles. In experiments it is observed they have small but nonzero masses. In the leptonic sector, it has been known that among the three mixing angles, two are large and the third one is small. This is known as bilarge mixing pattern. Both the above experimental facts indicates the extention of the Standard Model. More specifically, one has to understand the reason for the smallness of neutrino masses in comparison to other elementary particles and also about the bilarge mixing pattern. I have tried to understand these problems from a theoritical point of view in models like Little Higgs model, R-parity conserving/violating supersymmetric models.

We have proposed Majorana neutrino masses in the Littlest Higgs model in which standard lepton doublets interact with the Higgs triplet of the model. This generates neutrino masses of right order after electroweak symmetry breaking provided the vacuum expectation of neutral Higgs triplet scalar can be of order 0.1 eV. We have studied the decay branching ratios of triplet Higgs scalars into various modes and their collider implications.

We have made an attempt to understand the reason for the bilarge mixing pattern in the leptonic sector in a supersymmetric model in which hidden sector chiral superfields have been used to explain the mass of Higgsino particle which is also called as $\mu-$problem. We have proposed three right-handed Majorana neutrinos and nonrenormalizable interactions between hidden sector superfields and leptonic fields. We have introduced a specific superpotential of hidden sector fields to break supersymmetry and give masses to neutrinos. We have got neutrino mass matrix by seesaw as well as radiative effects. The unitary matrix which diagonlizes the neutrino mass matrix can be parametrized in terms of three mixing angles. We have explained the bilarge nature of mixing pattern in some numerical range of vacuum expectation values of the hidden sector superfields. We have applied this kind of idea in both R-parity conserving and R-parity violating supersymmetric models. In R-parity violating models, in addtion to what has been said above, right-handed neutrino fields can acquire vacuum expectation value. So, in order to explain neutrino masses of right order the vacuum expectation value of right-handed neutrino fields are constrained.

Publications:

1. T. Han, H.E. Logan, B. Mukhopadhyaya and R. Srikanth, " *Neutrino masses*

and lepton-number violation in the littlest Higgs scenario," Phys. Rev. D 72, 053007 (2005).

2. B. Mukhopadhyaya, P. Roy and R. Srikanth, *" Bilarge neutrino mixing from supersymmetry with high scale nonrenormalizable interactions,"* Phys. Rev. D 73, 035003 (2006).

Preprints:

1. B. Mukhopadhyaya and R. Srikanth, *" Bilarge neutrino mixing in R-parity violating supersymmetry: The Role of right-chiral neutrino superfields,"* , in preparation.

Conference/Workshops Attended:

1. June 2005: Study Group on Extra Dimensions at LHC, Harish-Chandra Research Institute, India.

2. January 2006: IX Workshop on High Energy Physics Phenomenology, Institute of Physics, India.

3. March 2006: Linear Collider Workshop (LCWS06), Indian Institute of Science, India.

Visits to other Institutes:

1. Department of Theoretical Physics, Tata Institute of Fundamental Research, India during 14-28 April, 2005.

Invited Lectures/Seminars:

1. April 2005: *Neutrino masses in the Littlest Higgs scenario* at Tata Institute of Fundamental Research, India.

2. March 2006: *Neutrino masses and the decay of triplet Higgs in the Littlest Higgs scenario* at Indian Institute of Science, India.

Other Activities:

1. I have participated in pheno lunch activities and presented some talks.

Rajeev Kumar Jain

Research Summary:

During the last year, my work has been focussed on understanding the origin and growth of cosmological perturbations in inflationary scenarios and the resulting signatures on the Cosmic Microwave Background (CMB). I have briefly described below some of the issues I have been investigating along with my supervisor L. Sriramkumar.

- *Scale-free spectrum from non-vacuum initial states:* Since slow roll inflation leads to a primordial spectrum that is nearly scale-independent, there prevails the notion that the initial state of the matter field is the Bunch-Davies vacuum. Non-vacuum initial states have been considered in the literature to either produce specific deviations from scale-invariance or to take into account possible high energy effects such as, say, trans-Planckian physics. We find that scale-indepedent spectra can also arise from non-vacuum initial states. With the help of a specific example, we show that, though, a strongly scale-dependent spectrum arises in the vacuum state, a nearly scale-free spectrum can be constructed in the same inflationary model from a suitably chosen squeezed state. Using the method of adiabatic regularization, we study the backreaction due to the excited states on the classical inflationary background.

- *Amplification of curvature perturbations at super-Hubble scales:* It is well-known that, in slow-roll inflation, the amplitude of the curvature perturbations 'freezes' to a constant value at super-Hubble scales. However, for the case of canonical scalar fields, it has been shown that, if there is a transition from a slow roll to a fast roll regime and then again to a slow roll phase, then the amplitude of curvature perturbations can grow at super-Hubble scales. We are presently examining the possibility of such behavior in the cases of scalar fields described by non-canonical actions.

- *k-inflation in higher dimensions:* We are also presently formulating perturbation theory for k-inflationary models in cosmological scenarios with extra dimensions. In this context, we will be investigating the effects of dynamical extra dimensions on the primordial perturbation spectrum.

Conference/Workshops Attended:

1. A symposium 'Einstein 1905' on April 12, 2005 at HRI, Allahabad.

2. A Symposium on 'String Theory - Basic Notions and Recent Developments' at HRI, Allahabad during Oct 1-2, 2005.

3. SERC Preparatory School in Theoretical High Energy Physics at HRI, Allahabad during Nov 6 - 25, 2005.

4. Young Astronomers' Meet (YAM) 2005 at IUCAA, Pune during Nov 29 - Dec 2, 2005.

5. An International Conference on 'Einstein's Legacy in the New Millennium' at Toshali Sands, Puri, India during Dec 15 - 22, 2005.

6. School on Cosmology and the Very Early Universe at IUCAA, Pune during Dec 25 - 30, 2005.

7. XXI SERC Main School in Theoretical High Energy Physics at PRL, Ahmedabad during Feb 11 - March 3, 2006.

Invited Lectures/Seminars:

I've listed below a few talks I gave at HRI.

1. A talk on *'Generation of Perturbations during Inflation'* on May 5, 2005.

2. A talk on *'Cosmological H-II regions and Photoionisation of the Inter-Galactic Medium'* on May 6, 2005.

3. A talk in the Astrophysics Journal Club on *'Comparison of tachyon inflation with standard (scalar field) Inflation'* on Sep 28, 2005.

Other Activities:

1. A talk on 'Gravitation' in Rajbhasha school, HRI during July 2005.

2. Helped in evaluating the papers (Physics) of HRI Science Talent Test 2005.

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Nishikanta Khandai

Research Summary:

Observational cosmology has made significant advances in the last decade and these observations provide useful constraints for theoretical models. Large-scale properties of the Universe can be understood using perturbation theory while small scale inhomogeneities become non-linear early on in their evolution and have to be studied using N-body simulations. There are further complications introduced by limitations of observations at these scales. The next generation of telescopes will reveal much on the formation of structures at these scales.
To understand structure formation and make proper predictions for these telescopes one requires N-body algorithms which are not only accurate and efficient but have a large dynamic range.

- *N-body Simulations:* We are currently working on improving the existing TreePM algorithm of Bagla,J.S. (J.Astrophys.Astron.23:185-196,2002) by introducing a variable softening length for the force, which will help resolve smaller scales. To do this one has to compute the local density around every particle. We are in the process of incorporating an efficient density routine in the existing TreePM algorithm.

- *HI as a Probe of Structure Formation:* Since neutral hydrogen (HI) is a good tracer of overdense regions one can use the signal (21cm line) emitted from HI, as a probe of Large Scale Structure. Earlier studies assigned the HI content in overdense regions in an ad-hoc manner. We are currently looking at refining this assignment of HI, by using the photoionisation equilibrium equation. This requires the knowledge of local temperatures which in turn require knowledge of the density. Yet again an efficient density routine is required to assign HI correctly.

- *Radio Maps from N-body Simulations:* Finally given the distribution of matter (from N-body simulations) and having assigned HI in a proper manner one has to go about making predictions for observations in existing and future generation telescopes. To do this one has to take into consideration the various telescope parameters (location, dimensions, noise, frequency window and bandwidth, etc.) to

  - predict the observation time to observe a structure of a given scale.
  - make mock radio maps of such structures.

  This part has been understood for single structures and more work is on to make predictions for statistical quantities (e.g. power spectrum).

Conference/Workshops Attended:

1. Young Astronomers' Meet (YAM) 2005 at IUCAA, Pune during Nov 29 - Dec 2, 2005.

Other Activities:

1. Completed the following courses at Linux Learning Centre, Bangalore during 4^{th} July - 13^{th} July 2005: LLC 103, LLC 203, LLC 303.

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Swarup Kumar Majee

Research Summary:

My current research interest lies on the topic of Universal Extra Dimension (UED) in high energy particle physics. During 2005-06, I have worked on the following topics

1. Power law evolution of different coupling constants in Universal Extra Dimension

Collaborators: Gautam Bhattacharyya, Anindya Datta, Amitava Raychaudhuri

We study the running of gauge, Yukawa, and quartic scalar couplings in the universal extra dimension (UED) scenario, where all the standard model particles can access all dimensions. We are interested for one extra space dimension which is compactified on an S^1/Z_2 orbifold with a radius $R \sim 1\mathrm{TeV}^{-1}, 5\mathrm{TeV}^{-1}, \mathrm{and}$ $20\mathrm{TeV}^{-1}$ for three different cases. We have considered one loop contributions from relevant KK towers of different particles to the above coupling constants upto a cutoff scale Λ. Due to this extra contribution, the logarithmic variation of the different couplings turns into power law running which forces couplings to unify at a very lower scale about $30\mathrm{TeV}$ for $R \sim 1\mathrm{TeV}^{-1}$. Finally we put upper and lower bounds on Higgs mass from the Landau pole and vacuum stability of the scalar potential conditions respectively.

Preprints:

1. *Power law blitzkrieg in Universal Extra Dimension* . (in preparation)

Conference/Workshops Attended:

1. Workshop on High Energy Particle Physics Phenomenology 9, Institute of Physics, Bhubaneswar, India, January, 2005.

Invited Lectures/Seminars:

1. Seminar at HRI on "Pentaquark - A multiquark theory " on September 2005

Other Activities:

1. **Pheno-lunch review talk**: Reviewed on the following papers:
   Studying The Effects of Minimal Length in Large Extra Dimensional Models in The Jet + Missing Energy Channels at Hadron Colliders. By Gautam Bhattacharyya, Kumar Rao, K. Sridhar e-Print Archive: hep-ph/0512050, December, 2005.

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Anamitra Mukherjee

Research Summary

Collaborators: My supervisior Prof. Pinaki Majumdar

We have studied a model involving orbitally degenerate e_g electrons and Jahn-Teller (JT) phonons in three dimensions. The electron-phonon coupling leads to an orbital ordered (OO) JT insulator at electron density around $n = 1$ per site. We have studied the evolution of orbital order with doping, the emergence of charge ordered phases, and metallisation of the Jahn-Teller insulator.

Collaborators: Prof. Sumathi Rao, Arijit Saha and Shamik Banerjee.

(1) Adiabatic quantum charge pumping through a dot at a junction of N quantum wires:

We have studied adiabatic charge pumping through a quantum dot placed at the junction of N quantum wires. We explicitly map out the pattern of pumped charge as a function of the time-varying tunneling parameters coupling the wires to the dot and the phase between the two time varying parameters controlling the shape of the dot. We find that the magnitude of pumped charges form an interesting pattern in the parameter space. Large pumped charges are only possible at an optimal value of the asymmetry, which is controlled by a combination of the pumping amplitude and the phase. Most of these features survive as N increases; however, the magnitude of the pumped charge decreases for the same asymmetry parameters.

Conference/Workshops Attended:

1. Presented poster, 'Numerical results of 3D Jahn Teller system' at "Indo-Japan conference on Giant Magnetoresistence mateials" held at Indian Institute of Science, Bangalore from 30th Jan- 2nd Feb.

Other Activities:

1. Project seminar on 'Electron phonon systems at strong couplings' on 28th July, 2005. This project was done with Prof. Pinaki Majumdar.

2. Condensed Matter group talk on 'Review of experiments on bilayer manganites' on 22nd Sept, 2005.

3. Condensed Matter group talk on 'Study of the 3D Jahn-Teller model-part 1' on 19th Jan, 2006.

4. Condensed Matter group talk on 'Study of the 3D Jahn-Teller model-part 2' on 16th Feb, 2006.

5. Tutor for 2nd semester (Jan 06 to April 06) Statistical Mechanics course taken by Prof.Ashoke Sen.

6. Delivered lecture for school students, under the Rajbhasha program, on 'rotational mechanics', on 28th May 2006.

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Kalpataru Pradhan

Research Summary:

I started my reserach with prof. Pinaki Majumdar after completing my project in july, 2005. In last year, I have worked on the full finite temperature diagram of the Kondo Lattice Model with classical spins, for arbitrary electron density (n) and electron-spin coupling (J) in three dimensions. We provide estimates of the transition temprature, and also the single particle density of states, resistivity, and optical response of the model for various (n,J,T), using the recently developed travelling cluster Approximation. We also use the variational approach for groundstate phase diagram.

Using same method and Kondo lattice model, we also calculated the transport and magnetic properties of diluted spin systems which is more closely related to study of diluted magnetic semiconductors. We also estimate the transition temperatures for various n and J and magnetic impurity conc.(x) , from which we conclude that with finite doping the transtion temerature is controlled by carrier density (carrier density is related to defects).

Preprints:

1. *The Variational Ground State and Finite Temperature Properties of Kondo Lattice Model with Classical Spins*: Kalpataru Pradhan and Pinaki Majumdar

Conference/Workshops Attended:

1. SERC school from 2nd january to 6th Jan, 2006 in SINP, Kolkata

Other Activities:

1. Project seminar on 28th july, 2005 (Magnetism and Transport in Diluted Spin Systems)
2. Condensed matter group talk on 9th feb, 2006 (Variational ground state and finite temprature properties of the classical Kondo lattice)

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Jayanti Prasad

Research Summary:

I have been working on various aspects of gravitational clustering in an expanding universe for the last one year. My work can be divided broadly into two parts.

- Mode coupling:- One of the important aspects of models of structure formation in the universe is to understand the interplay of cosmological perturbations at various scales which form galaxies, clusters of galaxies and other large scale structures in the universe, once amplified gravitationally. It has been known for a long time that there are significant effects of perturbations at large scales on small scales but not vice versa. In most of the studies these effects were quantified in terms of power spectrum and other second moments of density contrast. We have been trying to understand if there are any other effects of perturbations at small scales on large scales. We have found that substructures or small scales collapsed objects can help in relaxation of large scale perturbations. These results were obtained for an artificial model and now we plan to study these for generic models.

  This work is collaborated with Jasjeet singh Bagla and Suryadeep Ray.

- Finite box effects:- In cosmological N-Body simulations it is not possible to take into account perturbations at scales larger than the size of simulation box. This introduces errors in various measures of clustering like two point correlation function, mass function, comoving number density, merger rates and velocity measures. We have been developing analytical methods to estimate corrections in various physical quantities explicitly. We have found that the absence of perturbations at large scales underestimates comoving number density of large mass haloes, however, at this expense it overestimates it for low mass haloes. Apart, from mass function, we have been looking at effects of finite box size on other physical quantities also but this work in progress. We hope this type of studies will help to separate box size artifacts from real physical processes in cosmological N-Body simulation.

  This work is collaborated with Jasjeet singh Bagla.

Publications:

1. Bagla, J. S., Prasad, Jayanti, Ray, Suryadeep, 2005, MNRAS, **360**, 194

Preprints:

1. Bagla, J. S., Prasad, Jayanti, astro-ph/0601320

Conference/Workshops Attended:

1. Summer School (NOVICOSMO 2005), Novigrad, Croatia.

Visits to other Institutes:

1. Tata Institute of Fundamental Research (TIFR) Mumbai.
2. Inter University Center for Astronomy and Astrophysics (IUCAA) Pune.
3. Raman Research Institute (RRI) Bangalore.
4. Physics & Astrophysics department, Delhi University (DU) New Delhi.

Invited Lectures/Seminars:

1. TPSC seminar in TIFR, IUCAA, RRI & Delhi University.

Other Activities:

1. I have been involved with activities of popularizing Hindi at HRI under which I gave a science talk to school kids and helped in conducting talent search examination at HRI.

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Arijit Saha

Research Summary:

This work has been done with my supervisior Prof.Sumathi Rao and Anamitra Mukhejee.

We have studied adiabatic charge pumping through a quantum dot placed at the junction of N quantum wires. We explicitly map out the pattern of pumped charge as a function of the time-varying tunneling parameters coupling the wires to the dot and the phase between the two time varying parameters controlling the shape of the dot. We find that the magnitude of pumped charges form an interesting pattern in the parameter space. Large pumped charges are only possible at an optimal value of the asymmetry, which is controlled by a combination of the pumping amplitude and the phase. Most of these features survive as N increases; however, the magnitude of the pumped charge decreases for the same asymmetry parameters.

Other Activities:

1. Project seminar on 'Localization phenomena in weakly disordered systems' on 28th July, 2005. This project was done with Prof. Pinaki Majumdar.

2. Condensed Matter group talk on 'Adiabatic quantum charge pumping' on 15th Dec, 2005.

3. Tutor for 2nd semester (Jan to April) Statistical Mechanics course taken by Prof.Ashoke Sen.

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Bindusar Sahoo

Research Summary:

I along with my advisor prof Ashok Sen have been working on Higher derivative corrections to black hole entropy (Supersymmetric as well as Nonsupersymmetric)using the entropy function formalism devised by Ashok Sen(hep-th 0506177). The summary of our works are as follows:

1) We have analyzed the entropy of BTZ black holes in the presence of Chern Simons and Higher derivative terms using Walds Noether Charge method. In order to do this we treated the angular coordinate as a compact direction and reduced the theory from three to two dimension. The dimensional reduction of the Chern Simons term makes it covariant and one can apply Walds Noether charge method. We follow the alternative entropy function formalism to calculate the entropy for extremal BTZ black holes and find results for the entropy of Supersymmetric as well as Nonsupersymmetric black holes and find that our results matches with Krauss and Larsen results which they analyzed using Euclidean action formalism.

We also analyzed the entropy of non extremal BTZ black hole but since there is no entropy function formalism for non extremal black holes, we used Walds Noether Charge method directly to compute the entropy and found that our results matches with Krauss and Larsen results and finally we argued that an alternative entropy function formalism may be found for non extremal black holes as well.

2) Using the entropy function formalism we computed the entropy of extremal supersymmetric and non-supersymmetric black holes in $\mathbb{N}N = 2$ supergravity theories in four dimensions with higher derivative corrections. For supersymmetric black holes our results agreed with all previous analysis. However in some examples where the four dimensional theory is expected to arise from the dimensional reduction of a five dimensional theory, there was an apparent disagreement between our results for non-supersymmetric black holes and those obtained by using the five dimensional description. This indicates that for these theories supersymmetrization of the curvature squared term in four dimension does not produce all the terms which would come from the dimensional reduction of a five dimensional action with curvature squared terms.

Preprints:

1. Bindusar Sahoo, Ashoke Sen, *BTZ Black Hole with Chern-Simons and Higher Derivative Terms*

hep-th/0601228 (Submitted to JHEP)

2. Bindusar Sahoo, Ashoke Sen, *Higher Derivative Corrections to Non-supersymmetric Extremal Black Holes in N=2 Supergravity*
hep-th/0603149 (Submitted to JHEP)

Conference/Workshops Attended:

1. Attended the National String theory workshop held at IIT Kanpur from October 9th to October 16th 2005

2. Attended an International Conference on "Einstein Legacy in new Millenium" held at Toshali Sands, Puri from December 15-22, 2005

Other Activities:

1. Attended the 23rd Winter School in String theory held at Hebrew University Jerusalem from Dec 28 2005 to Jan 06 2006

2. Attended the XXI SERC THEP Main School held at PRL Ahmedabad from Feb 11 to March 3 2006

3. Attended the Spring School on Superstring theory and Related topics held at ICTP Trieste from March 27 to April 4 2006

4. Gave a talk on "Higher Derivative Correction to Black hole entropy" at HRI as a part of the requirement of the Graduate programme.

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Shashank Shalgar

Research Summary:

In the last one year I have studied the RG evolution in Standard Model and its extensions like Minimal Supersymmetric Standard Model and Grand Unified Theories.

Conference/Workshops Attended:

1. Attended SERC Particle Physics School held in PRL, Ahmedabad.
2. Attended Workshop on High Energy Particle Phenomenolgy in IOP, Bhubaneshwar.

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LECTURES / TALKS / SEMINARS AT THE INSTITUTE

MATHEMATICS

1.	Anupam Kumar Singh	Reality Properties of Conjugacy in G_2
2.	Sanoli Gun	Representation of Integers as sums of odd number of squares and special values of Dirichlet $L-$ functions
3.	Frank Neuman	Etale homotopy types of moduli stacks of algebraic curves
4.	Frank Neuman	Cohomology of moduli stacks of vector bundles and Frobenius morphisms
5.	T.B. Singh	Free actions on Lens spaces
6.	S.K. Khanduja	Tignol's constant and its relation with discriminant
7.	Urmie Ray	Structure of Borcherds Kac-Moody Lie Algebras
8.	Urmie Ray	Root Systems of Borcherds Kac-Moody Lie Algebras
9.	Urmie Ray	Introduction to Borcherds Kac-Moody algebras and their link with some Automorphic Forms
10.	Supriya A. Pisolkar	Classification of quaternion algebras over the field of rational numbers
11.	Tanusree Pal	Classification of Generalised Cartan Matrices
12.	S. Sarkar	Finite p-Group actions on Riemann Surfaces
13.	V.T. Aithal	Geometries of 3-manifolds

14.	Sidhartha Gadgil	Automorphisms of surfaces - 6 lectures
15.	Urmie Ray	Denominator Formulas and product expansions of automorphic forms for $O_{s+2,2}(\mathbf{R})^+$
16.	M. Prabhakar	Minimal Degree Sequence for Knots
17.	John Hubbard	Complex Analysis - 8 lectures
18.	Rabeya Basu	Results related to Serre's conjecture on Projective modules
19.	Ramji Lal	Represetation Theory of Groups - lecture series
20.	Georg Schumacher	Moduli of Weighted Punctured Riemann Surfaces
21.	Indranil Biswas	Atiyah-Weil criterion for existence of flat connection
22.	Georg Schumacher	Kaehler structures on moduli spaces
23.	P. Shastri	Local Class Field Theory
24.	Partha Guha	Geodesic Flows on Infinite Dimensional Groups and Integrable systems- 2 lectures
25.	R. Shukla	Introduction to Root Systems
26.	A.K. Singh	Variations on the theme of Chevalley
27.	D.S. Nagraj	On the desingularisation of unipotent variety
28.	S. Garge	Regular Elements of Semi-simple algebraic groups
29.	J. Adler	Endomorphisms of Linear Algebraic Groups
30.	Manish Thakur	Differential equations invariant under Finite reflection groups

31.	Ritumoni Sarma	Generators and relations for Chevalley groups
32.	John Ryan	Dirac operators, automorphic forms and some conformally flat manifolds
33.	C.K. Gupta	Automorphisms, Primitive systems, Test elements
34.	C.K. Gupta	Finite basis problem
35.	David Gauld	Dynamics on non-metrizable manifolds
36.	Manoj Yadav	Automorphisms of finite p-groups

LECTURES / TALKS / SEMINARS AT THE INSTITUTE

PHYSICS

1.	Suvankar Dutta	The AdS/CFT Correspondence
2.	Pravabati Chingangbam	Randall-Sundrum models- 3 lectures
3.	Suryadeep Ray	The 2dF Galaxy Redshift Survey: Higher Order Galaxy Correlation Functions
4.	S. Govindrajan	A quantum McKay correspondence for fractional 2p-branes on LG orbifolds
5.	S. Sengupta	Cosmological implications of a string inspired axion-electromagnetic coupling in a Randall-Sundrum Braneworld
6.	H.K. Jassal	Detection of the Baryon Acoustic Peak using Luminous Red Galaxies
7.	K.P. Yogendran	Long Strings in the 2D black hole
8.	B. Sahoo	Supersymmetric Field Theory
9.	N. Banerjee	The Asymptotic Freedom in QCD
10.	A. Mukherjee	The Supertrace Theorem and its Consequences
11.	Manoj Srivastava	Infrared Divergences and their treatment
12.	Anurag Tripathi	Renormalization Group-Wilsonian Approach
13.	Ayan Mukhopadhyay	A theory of interacting Brownian motors
14.	S. Goswami	Neutrino Oscillation and Mases

15.	S. Mohanty	Neutrino condensates in the early universe
16.	K.S. Babu	Neutrino masses and leptogenesis in minimal unified models
17.	Aswin Kumar	Evolution of Perturbations in a Spatially Flat Universe
18.	Neil Lambert	Distinguishing Off-shell Supergravities with On-Shell Physics
19.	P. Subramanian	Solar noise storm emission: Power estimates for electron acceleration
20.	P. Subramanian	Hybrid viscosity in two-temperature accretion disks around black holes
21.	Jayanti Prasad	The 2 dF Galaxy Redshift Survey: Power-spectrum analysis of the final dataset and cosmological implications
22.	L. Sriramkumar	Does scale-invariance imply slow-roll?
23.	Jainendra Jain	Whole hole electron in a fractionalized liquid
24.	K. Panigrahi	D-brane dynamics in curved backgrounds
25.	K. Sengupta	Edge states in unconventional superconductors
26.	S. Ghosh	Quantum Mechanics of Vortex Motion in Two Dimensions
27.	Justin r. David	Planar $N = 4$ SYM at One Loop and String Bits
28.	J. Majumdar	Crosscaps in Gepner models and type IIA Orientifolds
29.	Nilmani Mathur	The Hadronic Physics from Lattice QCD
30.	S. S. Deshingkar	Gravitational wave extraction in numerical relativity
31.	Monika Sinha	Strange Quark Matter and Astrophysical Observations

32.	Swarup K. Majee	Pentaquark – a multiquark theory
33.	Rajeev Kumar Jain	Comparison of Tachyonic Inflation with standard (Scalar field) Inflation
34.	D.P. Roy	An Overview of Solar Neutrino Oscillations
35.	T. Gupta	The Role of Coulomb Glass Repulsion in the Phase Segregation Problem in Manganites, The Coulomb Glass
36.	C. Muthu	Astrophysical Dust: Importance, Nature and Origin
37.	K.M. Kolwankar	Local Fractional Calculus: Stochastic Aspects
38.	S. S. Deshingkar	c is the speed of light, isn't it?
39.	Ayan Mukhopadhyay	Black Hole Entropy in Higher Derivative Gravity
40.	Justin R. David	Planar N = 4 SYM at One Loop and String Bits
41.	Poonam Mehta	Determining the neutrino mass hierarchy with atmospheric neutrinos
42.	J. Bapatista	On Vortex Moduli Space
43.	Amitabh Virmani	A Black Hole Instability in Five Dimensions
44.	K. Jain	Evolutionary trajectories in rugged fitness landscapes
45.	Tapas Das	Steady shocks around Black holes produced by sub-keplerian flows with negative energy
46.	D. Sen	Equation of motion approach to quantum wire problems
47.	H.K. Jassal	The Supernova Legacy Survey: Measurement of Ω_M, Ω_Λ and ω

48.	S.K. Rai	Associated single photons as signals for a doubly charged scalar at linear $e^- - e^-$ colliders
49.	A. K Ray	Critical solutions and large scale properties of an accretion disc
50.	Tapas Das	Observational Evidence of Jet Precession in Galactic Nuclei Caused by Accretion Disks
51.	David Gross	The Coming Revolutions in Fundamental Physics
52.	D. Gaiotto	Counting Black Hole Microstates with Holography
53.	R.P. Jena	A C-function for Non-Supersymmetric Attractors
54.	P. Majumdar	Stringlike behaviour of QCD flux tubes
55.	A. Nyffeler	The search for New Physics: An approach with Effective Field Theories - 3 lectures
56.	J.S. Bagla	The Pre-Reionisation Universe: From first stars to reionisation
57.	S. Sur	Charged black holes in generalized dilator-axion gravity and observational implications
58.	N. Khandai	Teh HII region of the first star
59.	T. Stauber	Optical Absorption in Quantum Dots: Coupling to Longitudinal Phonons treated exactly
60.	T. Stauber	Flow Equations for Hamiltonians and Dissipative Models
61.	H.K. Jassal	The paths of Quintessence
62.	J. Prasad	Why is the Zel'dovich approximation so accurate?
63.	Chandrasekhar	Random Walk: From classical to quantum and exploring its implementations

64.	L. Sriramkumar	The Universe according to WMAP: Three Years of Observations and its Implications for Cosmology
65.	A. Rajaraman	the eight-derivative action in M-theory
66.	S. Dutta	On Euclidean and Noetherian Entropies in AdS Space
67.	K. Goldstein	Rotating Attractors

COLLOQUIUM

JOINTLY ORGANISED BY MATHS & PHYSICS

1.	Vinod Gaur	Earthquake and Tsunami Threats to India
2.	John Hubbard	The dynamics of the forced pendulum
3.	J. Jain	Topological fermions in condensed matter physics
4.	D.P.Roy	Basic Constituents of Matter-Visible and Invisible
5.	N. K. Mondal	India Based Neutrino Observatory
6.	Florian Luca	Euler's ϕ function
7.	Hermann Nicolai	Loop Quantum Gravity: A view from outside
8.	Robert P. Langlands	Seeing the Theory of Automorphic Forms Whole
9.	Olivier Ramare	The large sieve with sparse sets of moduli and amplitudes

HRI-Triveni Lectures

1.	**David Gross**	*The Future of Physics*	31^{st} January, 06
2.	**Robert P. Langlands**	*Reflections on the legacy of Harish-Chandra*	15^{th} February, 06

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PUBLICATIONS :

Sukumar Das Adhikari

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2. *Contributions to zero–sum problems.* (Jointly with Y. G. Chen, J. B. Friedlander, S. V. Konyagin and F. Pappalardi) Discrete Math. **306**, 1–10 (2006).

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Punita Batra

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- *Class numbers of real quadartic fields with many distinct prime factors* (with A. Mukhopadhaya and F. Luca).

Chandan Singh Dalawat

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- *Good reduction, bad reduction*.
- *The Tao of Mathematics, and Think Locally*.
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- *An inverse system of nonempty objects with empty limit*, (with V.V.Awasthi), communicated.

- *Homology and Dimension- Further pathological examples* (with V.V.Awasthi), under submission.
- *Torsion in the group of homeomorphisms of the product of long rays and long lines* (with David Gauld). (in preparation)

Rukmini Dey

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(With Satya Deo).
- Homology and Dimension - Further pathological examples.
(With Satya Deo).

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Purusottam Rath

- *A problem on the fractional parts of the powers of* $3/2$ *and related questions.*
  (Jointly with S.D.Adhikari)
  Submitted

- *On Davenport's Constant*
  (Jointly with K. Srilakshmi and R. Thangadurai)
  Submitted

Brundaban Sahu

- (with B. Ramakrishnan) *On the Fourier Expansions of Jacobi Forms of Half-Integral Weight.*

- (with B. Ramakrishnan) *Rankin-Cohen Brackets and Jacobi forms on* $\mathbb{H} \times \mathbb{C}^g$.

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2. Bagla J. S., Prasad Jayanti and Ray Suryadeep 2005,MNRAS 360, 194: *Gravitational collapse in an expanding background and the role of substructure I: Planar collapse.*
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2. Das, T. K. (with Abraham H, & Bilić, N.), 2006, *Acoustic Horizons in an Axially Symmetric Relativistic Accretion*, Classical and Quantum Gravity, 23, 2371.

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5. D. P. Jatkar and A. Sen, *Dyon spectrum in CHL models,* JHEP **0604**, 018 (2006) [arXiv:hep-th/0510147].
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7. J. R. David, D. P. Jatkar and A. Sen, *Product representation of dyon partition function in CHL models,* arXiv:hep-th/0602254 (to appear in JHEP).

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- Bagla J. S. and Prasad Jayanti 2006, astro-ph/0601320: *Effects of the size of cosmological N-Body simulations on physical quantities — I: Mass Function*.
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Justin R. David

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- *"From spacetime to worldsheet: Four point correlators,"* J. R. David and R. Gopakumar. (in preparation)

Kazuyuki Furuuchi

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About the Library

The library is one of the best equipped libraries in India. Being a research oriented institute, it provides the required support to the academic and research activities. It remains open on all working days from 8 am to 2 am including Saturdays. It also remains open during the Sundays and the Gazetted holidays from 10 a.m. to 6 p.m. It added 420 (four hundred twenty) volumes in its fold including 361 books and 59 as gifted. It also added 2560 bound volumes of the journals during the period from 1st April 2005 to 31st March 2006. It has a total collection of 42825 (Forty two thousand eight hundred twenty five) of books and bound volumes. It subscribed 222 journals during the period under report. It includes 105 as online journals.

During the last year basic emphasis was provided to the conversion of the Video Cassettes to VCD format for durability. Recently the library web page has been reconstructed which provides more detailed information about the library such as subscribed databases, archives, library rules, library staff, list of online journals, online link to the Video lectures and other useful links. The emphasis was also given to procure maximum number of journals on line. We have been providing on-line access of the periodical to our users for 105(One hundred five) titles.

We provided the Web Enabled library catalogue to our users. The library can be termed as completely automated library system, which includes acquisition, cataloging, circulation, search modules etc. This on-line catalogue had increased the opportunities of the use of our library resources by the neighboring organizations such as INSDOC, TIFR etc. through the Document Delivery Services (DDS). Normally we provide the DDS on request through post, at very nominal cost, but requests had also been honoured through e-mail. We had encouraged the use of the library by providing the library consultation facilities to the research scholars from the neighboring institutes. We had strengthened our library security with the implementation of Electro-magnetic Tattle Tapes to reduce the losses.

ABOUT THE COMPUTER SECTION

1. All the computers of the administrative staff members were upgraded with Pentium 3.4 GHz machines.
2. Windows XP operating system was loaded on all the computers of the administrative staff.
3. Few more laptops were procured to be used for giving presentations and doing computing work when on a visit.
4. Newer versions of Linux operating systems were purchased. Operating systems of users' desktop and other systems were upgraded.
5. Anti-Virus software is installed on all the windows computers.
6. New Pentium machines were purchased and installed with Windows XP and Linux operating systems in the conference computer room.
7. Computing related to conferences were held in the conference computer room.
8. New HP laser printers were purchased and installed in the computer center and hub rooms.
9. Purchase order has been placed for the purchase of new pentium based computer systems for all the faculty members.
10. Broadband Internet connectivity with 1 Mbps, full duplex, 1:1, assured bandwidth was procured and made operational from Sify Limited.

Current Activities and plans

1. Expansion of the local area network in the offices of the first floor library building is in the process.
2. Purchase of a 20 KVA ONLINE UPS system is being planned to provide the uninteruppted power supply in the offices of the first floor library building.
3. Procuring a few more laptops is being planned.
4. Upgradation of the existing Sify Broadband Internet connectivity from 1 Mbps, full duplex, 1:1, to 2 Mbps, full duplex 1:1 is under process.

5. Purchase of a good quality, high speed A3 size colour laser printer is under process.
6. Purchase of small size laser printers for all the faculty members is under process.
7. Expansion of the campus network in the newly constructed E-Type flats (6 Nos.) is in the process.

CONSTRUCTION WORK AT THE CAMPUS

- Some new buildings i.e. Hostel-3, Guesthouse & Library Extension and Engineering Building are to be constructed. For these buildings Engineering Consultancy Services is required. In this connection exercise is under process for choosing of Engineering Consultant.
- Since power roistering is increasing every year therefore Institute is trying to get 33 KVA uninterrupted power supply line directly from 132 KVA Substation (Hanumanganj). In this connection necessary exercise has already been done. Now estimate is awaited from UPPCL for further action.
- As per Council decision the library building has been renamed after Shri. Girdhari Lal Mehta. A name plate (GIRDHARI LAL MEHTA BHAVAN) has been fixed there for the same.
- Construction of 6 nos. type V/E quarters, roads, storm water drain etc. are completed and ready for use.
- Supplying and fixing of AC grill shutter in the rooms of Institute building is completed and made fully functional and are in use.

VIGILANCE ACTIVITIES AT THE CAMPUS

There is nothing to report from vigilance point of view for the period upto March 31, 2006.