HARISH-CHANDRA RESEARCH INSTITUTE

ACADEMIC REPORT
(2007-08)

Chhatnag Road , Jhunsi , Allahabad - 211 019 , India

CONTENTS

ABOUT THE INSTITUTE

THE EARLY YEARS

The Harish-Chandra Research Institute is one of the premier research institutes in the country. It is an autonomous institute fully funded by the Department of Atomic Energy, Government of India. 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 N. D. Tiwari, 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 1990, finally, about 66 acres of land was acquired in Jhunsi, Allahabad and the institute has since came up at this site .

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. After the tenure of Prof. Kulkarni, Prof. Amitava Raychaudhuri has taken over as Director with effect from 19.07.2005. The Institute continues to be devoted to fundamental research in diverse areas of Mathematics and Theoretical Physics. Research is carried out by about 33 faculty members, visiting faculty, post-doctoral fellows, and Ph.D. students numbering around 52. Since the year 1992 the institute has attracted worldwide attention, as is evident from the recognition received by many of its faculty members, both at the national and international levels. Among them

Prof. Ashoke Sen, Prof. A. Raychaudhuri, Prof. B. Mukhopadhyaya and Prof. Pinaki Majumdar are all winners of the prestigious S.S. Bhatnagar award. Prof. Ashoke Sen was also honoured through the Padmashree Award, election to the Fellowship of the Royal Society, and award of the INSA S.N. Bose Medal and the prestigious J.C. Bose Fellowship of the Dept. of Science and Technology. Prof. Rajesh Gopakumar won the Swarnajayanti Fellowship of the Dept. of Science and Technology and the coveted ICTP prize for 2006. Professor Sukumar Das Adhikari was elected a Fellow of the National Academy of Sciences, India, in 2007.

RESEARCH IN MATHEMATICS

The mathematics group at HRI carries out research in several areas. In algebra, we are engaged in the study of algebraic groups and related structures, the theory of groups and group rings, representation theory, and infinite-dimensional Lie algebra. The work at HRI in analysis is in the field of harmonic analysis of Lie groups. The activity in geometry includes discontinuous groups and Riemann surfaces, algebraic topology, variational problems on manifolds, Chow groups of rational surfaces, and moduli of vector bundles. The number theory group works on algebraic, analytic and combinatorial number theory, automorphic forms and cryptography.

RESEARCH IN PHYSICS

At HRI, research in theoretical physics in carried out in the fields of astrophysics, condensed matter physics, high energy phenomenology and string theory. In astrophysics, the faculty is involved in the investigation of the cosmic microwave background radiation, the large scale structure of the universe and the evolution of galaxies. The main areas of activity in condensed matter physics are strongly correlated electron systems, mesoscopic systems, quantum Hall effect and superconductivity. In string theory, perturbative and non-perturbative aspects of string theory and quantum field theory are being actively investigated. In high energy phenomenology, research is carried out in the following areas: neutrino physics, strong interactions, lattice gauge theory, supersymmetry and various aspects of physics beyond the standard model. The Institute is a member of the INO collaboration.

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.

DIRECTOR'S REPORT

At the Harish-Chandra Research Institute (HRI) the year 2007-08 was marked by a number of noteworthy events. Before I spell these out in detail let me mention that the emphasis at HRI has remained, as before, to achieve further excellence in the fields of mathematics and theoretical physics. The innovative research activities as well as the pre-Ph.D. teaching programme at HRI have continued to be at the highest level. This has been possible through the sustained efforts of our scientists, post-doctoral fellows, students, and visitors to continuously upgrade themselves to remain at the frontiers of international research. They were assisted in no small measure by the steadfast administrative support from the entire institute staff. All members of HRI have a deep sense of belonging with the Institute and is willing to walk the extra mile to ensure that it steadily progresses towards further national and international recognition.

HRI is a proud member of a group of autonomous Institutes generously funded by the Department of Atomic Energy (DAE), Government of India. The activities at HRI fit well with the Department's identified R&D targets through its Specialist Groups. In the XIth Five-year Plan, which began in 2007, HRI has been sanctioned a number of projects which will lead to all-round development. This includes a Regional Centre for Accelerator-Based Particle Physics geared to create a pool of manpower – both faculty and students from HRI as well as in universities and other institutes – all trained to fully exploit the much-awaited results from the Large Hadron Collider, to be turned on at CERN (Geneva) later this year. There is also an ambitious plan to build several new cluster computers. Here, HRI was a pioneer in the country and several cluster computers set up under the Xth Plan have become the workhorses for the entire scientific computing activities related to the different research groups. Besides these, collaboration meetings in the areas in which the Institute is internationally acclaimed, workshops, training school programmes, outreach activities, will all be enhanced. There are ambitious plans to set up a new hostel to accommodate an increased student intake as well as expansion plans for the library and administrative areas.

HRI is a Constituent Institute (CI) of the Homi Bhabha National Institute (HBNI). Two students of HRI are in the final stages of submitting their Ph.D. theses to HBNI later in 2008. The CIs of HBNI – DAE units and aided-institutes all – form a close-knit family. HRI post-B.Sc. integrated Ph.D. students are going to spend the summer of 2008 at RRCAT, Indore and SINP, Kolkata for their laboratory training. Also, research training courses for the India-based Neutrino Observatory –

of which many DAE units and Institutes are partners – will be undertaken at HRI.

The Institute has completed an External Peer Review to assess its progress and to identify directions for future development. The Review Panel consisted of Professors M.S. Narasimhan (TIFR, Bangalore, Chair), Jean-Marc Deshouillers (Bordeaux, France), John Ellis (CERN, Switzerland), Jainendra K. Jain (Penn State, USA), Rajaram Nityananda (NCRA, Pune), and Joseph Oesterlé (Paris, France). This Review took place in two sittings: one in February 2007 and again in November 2007. The Report has been submitted to the HRI Governing Council. It suggests directions for the Institute to focus on in the future and possible areas of expansion.

HRI has continued to maintain its popularity among intending Ph.D. students. Out of the top ten students in this year's physics JEST examination, seven had offered HRI as the first preference. There are also many applications from inside as well as outside the country for post-doctoral positions at the Institute.

In 2007-08, seven students joined the Ph.D. programme in physics. Three of them were post-B.Sc./B.Tech. who enrolled for the integrated Ph.D. scheme. The post-B.Sc. students attend an additional year of course work and undertake laboratory training in some sister institutes.

In mathematics, this year two students have joined the Ph.D. programme through the HRI selection procedure. Besides, one student has joined with support from an NBHM fellowship.

To alleviate problems due to frequent outage of the UPPCL power, HRI has to maintain an alternate power supply arrangement through three generator sets. The maintenance and running costs of these machines is steadily increasing. HRI has decided to improve the power situation through a dedicated 33kV connection from UPPCL. This way the load-shedding will be almost completely avoided. Work in this direction has made significant progress and we are optimistic that an uninterrupted power supply will be arranged for the Institute soon.

The scientific research at the Institute is published in leading international journals and attract wide attention. Many are well-cited by others working in the same areas. The scientists are invited to present their work at many conferences and meetings. HRI also hosts a fair number of collaboration meetings throughout the year. The Institute's Ph.Ds are offered post-doctoral appointments at top-class institutions around the world. A number of the early HRI Ph.Ds have been picked up in permanent positions by leading research institutes.

Manoj Kumar Yadav is the newest faculty member to join the Institute. He works in the area of Algebra and will further strengthen the HRI mathematics group.

The members of the Institute have continued to win laurels. Let me list some of those:

- Professor Pinaki Majumdar was selected for the Shanti Swarup Bhatnagar Award in the Physical Sciences in 2007.
- Professor Sukumar Das Adhikari was elected a Fellow of the National Academy of Sciences, India.

The year ahead looks promising for the Harish-Chandra Research Institute.

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. V. R. Sadasivan (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)	Saha Institute of Nuclear Physics 1/AF, Bidhannagar Kolkata - 700 064

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. Miyan Jan (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. Sukumar Das Adhikari
2. Dr. Punita Batra
3. Dr. Kalyan Chakraborty
4. Dr. C. S. Dalawat
5. Dr. Rukmini Dey
6. Dr. Ratnakumar P. K.
7. Dr. N. Raghavendra
8. Prof. B. Ramakrishnan
9. Dr. D. Surya Ramana
10. Dr. R. Thangadurai
11. Dr. Manoj Kumar

Visiting Professor (Mathematics)

1. Prof. S. D. Tripathi

Visiting Scientist (Mathematics)

1. Dr. Ioulia Baoulina

Visiting Fellow (Mathematics)

1. Dr. Sameer Laxman Chavan
2. Dr. Jung- Jo Lee
3. Dr. Prabal Paul
4. Dr. Gyan Prakash

Research Scholar (Mathematics)

1. Mr. Sanjay Kumar H. Amrutiya
2. Mr. Mohan Namdev Chintamani
3. Mr. Soumya Das
4. Mr. Moriya Bhavin K.
5. Mr. Jaban Meher
6. Ms. Indira Mishra
7. Ms. Archana S. Morye
8. Ms. Tanusree Pal
9. Ms. Supriya A. Pisolkar
10. Mr. Brundaban Sahu
11. Mr. Karam Deo Shankhadhar
12. Mr. Mahender Singh
13. Mr. Vijay Kumar Sohani

Faculty Members (Physics)

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

Visiting Professor (Physics)

1. Prof. M. K. Parida

Visiting Scientist (Physics)

1. Dr. H. K. Jassal
2. Dr. Andreas Nyffeler

Visiting Fellow (Physics)

1. Dr. Abhijit Bandhopadhyaya
2. Dr. Paramita Dey
3. Dr. Theodre G. Erler
4. Dr. Bindu S. Govindan
5. Dr. Soumitra Nandi
6. Dr. Prabuddha Sanyal
7. Dr. Yogesh Kumar Srivastava
8. Dr. Atsushi Watanabe

Research Scholar (Physics)

1. Mr. Kumar Abhinav
2. Mr. Sanjib Kumar Agarwalla
3. Mr. Ramlal Awasthi
4. Mr. Arjun Bagchi
5. Mr. Priyotosh Bandyopadhyay
6. Ms. Nabamita Banerjee
7. Mr. Shamik Banerjee
8. Mr. Atri Bhattacharya
9. Mr. Subhaditya Bhattacharya

10. Mr. Sanjoy Biswas
11. Mr. Turbasu Biswas
12. Mr. Joydeep Chakraborty
13. Ms. Nishita D. Desai
14. Mr. Suvankar Dutta
15. Mr. Rajesh Kumar Gupta
16. Mr. Sudhir Kumar Gupta
17. Mr. Dhiraj Kumar Hazra
18. Mr. Rajeev Kumar Jain
19. Mr. Nishikanta Khandai
20. Mr. Girish P. Kulkarni
21. Mr. Arijit Kundu
22. Mr. Shailesh Lal
23. Mr. Swarup Kumar Majee
24. Ms. Ipsita Mandal
25. Mr. Manoj Kumar Mandal
26. Ms. Manimala Mitra
27. Mr. Anamitra Mukherjee
28. Mr. Ayan Mukhopadhyay
29. Mr. Satyanarayan Mukhopadhyay
30. Mr. Kalpataru Pradhan
31. Mr. Arun Ramachandran
32. Mr. Arijit Saha
33. Mr. Bindusar Sahoo
34. Mr. Viveka Nand Singh

35. Ms. Simi R. Thomas
36. Mr. Rajarshi Tiwari
37. Mr. Anurag Tripathi

ADMINISTRATIVE STAFF

1.	Shri P.B. Chakraborty	Registrar (from 05.07.06)
2.	Shri Raaj Kumar Gulati	Accounts Officer
3.	Dr. V. R. Tiwari	Librarian
4.	Shri Prabhat Kumar	Senior Private Secretary
5.	Shri Amit Roy	Internal Audit cum Admn. Officer
6.	Shri K.S. Shukla	Professional Assistant
7.	Shri Jagannath Yadav	Accountant
8.	Shri R. P. Sharma	Guest House Manager
9.	Dr. Archana Tandon	Office Superintendent
10.	Shri Deepak Srivastava	Store Purchase Officer
11.	Shri Uma Kant Dwivedi	Cashier
12.	Shri D. Malhotra	UDC
13.	Shri K. K. Srivastava	UDC
14.	Shri Yashpal Singh	Steno
15.	Mrs Sumitra	UDC
16.	Shri Parmanand Mishra	Jr. Library Assistant
17.	Shri Dharm Pal Sharma	Jr. Library Assistant
18.	Mrs Seema Agarwal	Receptionist
19.	Shri Kashi Prasad	Driver
20.	Shri Dina Nath Dubey	Bearer (Canteen Cadre)
21.	Shri Lalloo Ram	Bearer (Canteen Cadre)
22.	Shri Kamlesh Thakur	Bearer (Canteen Cadre)
23.	Shri Ramakant Dixit	Watchman/Peon
24.	Shri Kamta Prasad	Watchman/Peon
25.	Shri Rajesh Kumar	Sweeper
26.	Shri Munna Lal	Gardener

Engineering/Technical Staff:

1.	Shri Manish Sharma	Scientific Officer 'C'
2.	Shri Sanjai Verma	Systems Manager
3.	Ms. Anju Verma	Scientific Asstt.
4.	Shri Ajay Kumar Srivastava	Jr. Engineer (Electrical)
5.	Shri V. K. Srivastava	Jr. Engineer (Civil)

Project Assistants:

1.	Mr. Shahid Ali Farooqui	Project System Manager (cluster Project)

Medical Consultants/Pharmacists:

1.	Dr. G. S. Sinha	Authorised Medical Consultant
2.	Dr. Bharat Arora	Emergency Medical Officer
3.	Dr. Md. Osama Jafri	Emergency Medical Officer
4.	Dr. Nidhi Mishra	Emergency Medical Officer
5.	Dr. S. D. Pandey	Emergency Medical Officer
6.	Dr. Rakesh Verma	Emergency Medical Officer
7.	Shri S. R. Gautam	Sr. Pharmacist
8.	Shri Piyush Dixit	Pharmacist
9.	Shri Alok Pandey	Pharmacist
10.	Miss Shilpi Srivastava	Pharmacist

ACADEMIC REPORT - MATHEMATICS

Sukumar Das Adhikari

Research Summary:

For the particular group $\mathbf{Z}/n\mathbf{Z}$, certain weighted generalizations of some combinatorial group invariants were considered. These were further generalized and expected relations between these constants were established under certain conditions. These investigations are being followed up. Work is also in progress in some areas related to Diophantine approximations.

Publications:

1. S. D. Adhikari and Y. G. Chen, *Davenport constant with weights and some related questions - II*, J. Combinatorial Theory, Ser. A, **115**, 178–184 (2008).

2. S. D. Adhikari, R. Balasubramanian and P. Rath, *Some combinatorial group invariants and their generalizations with weights*, Additive Combinatorics, (Eds. Granville, Nathanson, Solymosi), 327 – 335, CRM Proceedings and Lecture Notes, Volume 43, American Mathematical Society, 2007.

3. S. D. Adhikari, R. Balasubramanian, F. Pappalardi and P. Rath, *Some zero-sum constants with weights*, Proc. Indian Acad. Sci. (Math. Sci.), to appear.

4. Sukumar Das Adhikari, Stephan Baier and Purusottam Rath, *An extremal problem in lattice point combinatorics*, Diophantine Equations, N. Saradha Ed., Tata Institute of Fundamental Research, to appear.

5. S. D. Adhikari and P. Rath, *A problem on the fractional parts of the powers of* $3/2$ *and related questions*, Proc. Int. Conf. - Number Theory and Discrete Geometry, the proceedings of a conference held at Chandigarh University in honour of Prof. R. P. Bambah, to appear.

Conference/Workshops Attended:

1. National Conference on Scientific Applications of Mathematics at Bhavan's Mehta P. G. College, Bharwari, on December 23, 2007.

2. International Conference on Frontier of Mathematics & Applications (ICFMA-2008) held in the Department of mathematics, University of Burdwan, Burdwan, during 16-18 January, 2008.

3. *Workshop on Topological Dynamics, Diff. Equations and Applications* at the Dept. of Mathematics and Statistics, University of Hyderabad, Hyderabad, March, 2008.

Visits to other Institutes:

1. The Institute of Mathematical Sciences, Chennai, during May 14 - 18, 2007.
2. Belur Vidyamandir, India, in July and September, 2007.
3. Department of Mathematics, IISc, Bangalore in September, 2007.
4. Visited the Department of Mathematics, Niigata University during February 2008.
5. Visited the Department of Mathematics, Ramakrishna Mission Vivekananda University, Belur for three weeks in March 2008.

Invited Lectures/Seminars:

1. Gave a talk in The Institute of Mathematical Sciences, Chennai, in May 2007.
2. Gave a talk in the Department of Mathematics, IISc, Bangalore on 5.9.2007.
3. Gave a talk in the Department of Mathematics, University of Burdwan, Burdwan, on 18.09.2007.
4. Gave a course of lectures in the Advanced Instructional School in Algebraic and Analytic Number Theory, held at HRI during December 3-28, 2007.
5. Gave an invited talk in the National Conference on Scientific Applications of Mathematics at Bhavan's Mehta P. G. College, Bharwari, on December 23, 2007.
6. Gave an invited talk the International Conference on Frontier of Mathematics & Applications (ICFMA-2008) held in the Department of mathematics, University of Burdwan, Burdwan, during 16-18 January, 2008.
7. Gave a talk in Department of mathematics, Niigata University, Japan, during February 2008.
8. Gave an invited talk in the *Meigaku Seminar* at Nihon University on 9 February, 2008.

9. Gave a course of lectures in Algebraic Number Theory in the Department of Mathematics, Ramakrishna Mission Vivekananda University, Belur, in March 2008.

Academic recognitions:

1. Elected a fellow of the National Academy of Sciences, India.
2. Adjunct Professor in the Department of Mathematics in Ramakrishna Mission Vivekananda University, Belur.

Other Activities:

1. Gave a course on Algebra to first year students and supervised one seminar course.
2. Supervised Ph. D. work of Ms. Anupama Panigrahi who has recently submitted her Ph. D. thesis in Allahabad University.
3. Was one of the coordinators of the Advanced Instructional School in Algebraic and Analytic Number Theory, held at HRI during December 3-28, 2007.

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Punita Batra

Research Summary:

I took the problem of finding the highest weight representations of pre-exp-polynomial Lie algebras. In a joint work with Xiangqian Guo, Rencai Lu and Kaiming Zhao, we showed that non-graded and graded irreducible highest weight modules with the same highest weight have finite dimensional weight spaces if and only if the highest weight is an exp-polynomial highest weight. We also showed that non-graded and graded highest weight Verma modules with the same highest weight are simultaneously irreducible or not. We determined necessary and sufficient conditions for a Verma module to be irreducible.

Publications:

1. S. Eswara Rao and Punita Batra, *Classification of irreducible integrable modules for twisted toroidal Lie algebras with finite dimensional weight spaces,* Pacific Journal of Mathematics, Vol. 237, No.1, 151-181, (2008).

Preprints:

1. Punita Batra, Xiangqian Guo, Rencai Lu and Kaiming Zhao, *Highest weight modules over pre-exp-polynomial Lie algebras,* submitted for publication.

Conference/Workshops Attended:

1. *Workshop on "Lie Theory"*, MSRI, Berkeley USA, 10-14 March, 2008.

Visits to other Institutes:

1. TIFR, Bombay, 18-24 October, 2007.
2. San José State University, CA USA, 12 March, 2008.

Invited Lectures/Seminars:

1. *Finite and Infinite dimensional Lie algebras and representation Theory*, San José State University, CA, 12 March, 2008.

Other Activities:

1. Gave a lecture on "Group Theory" in KVPY at HRI in May, 2007.

2. Gave six lectures on "Finite Fields" in Summer Programme in Mathematics(SPIM) at HRI in June, 2007.

3. Gave two lectures in the Rajbhasha scientific workshop at HRI in July, 2007.

4. Conducted the mathematics part of the Annual Science Talent Test in November, 2007.

5. Gave a lecture in AIS on Algebraic and Analytic Number Theory on "Characters of finite abelian groups" at HRI in December, 2007.

6. Gave a second year graduate course "Topics in Algebra" at HRI during January - May, 2008.

7. Convener of Mathematics Visitor's Committee of HRI from September 2007. Also serving as a member in the Sports and Entertainment Committee and the Rajbhasha Committee.

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Kalyan Chakraborty

Research Summary:

In a joint work with Florian Luca we have studied the positive integers n such that for some $g > 1, (n^g)^2 + 1 = dv^2$, but the pair $(U, V) = (n^g, v)$ is not the minimal solution of the Pell equation $U^2 + 1 = dV^2$. We provide a sharp upper bound for the counting function of such positive integers n.

In another joint work with Florian Luca we are studying the solutions of the Diophantine system of equations $a + b + c + d = abcd = 1$ in the ring of integers of quadratic fields.

In a joint work with Shigeru Kanemitsu and J. -H. Li we studied some manifestations of the Perseval Identity in number theory.

Work is in progress along with Loic Merel in developing modular symbols for number fields and use these symbols to study special values of twisted L-functions associated to automorphic forms.

Publications:

1. K. Chakraborty *On the Diophantine equation* $x + y + z = xyz = 1$ Annales Univ. Sci. Budapest., Sect. Comp. **Vol. 27**, 145–154 (2007)

2. Kalyan Chakraborty, Florian Luca and Anirban Mukhopadhyay *Exponents of class groups of real quadratic fields,* Intl. Journal of Num. Theory , To Appear, (2008)

3. Kalyan Chakraborty, Florian Luca and Anirban Mukhopadhyay *Class numbers with many prime factors,* Journal of Num. Theory , To Appear

Preprints:

1. Kalyan Chakraborty, Florian luca *Perfect powers in solutions to pell equations* Preprint

2. Kalyan Chakraborty, Shigeru Kanemitsu and J. -H Li *Manifestations of Parseval Identity* Preprint

3. Kalyan Chakraborty, Florian Luca, *On the solutions of the Diophantine equation* $a+b+c+d = abcd = 1$ *in the ring of integers of quadratic fields,* (in preparation)

Conference/Workshops Attended:

1. *Conference in Number Theory and applications*, Chennai, September 2007.
2. *Mathematics and Applications - Recent trends (Mart 2008)*, India, November 2007.
3. *Fourth North West Number theory Conference*, China, March 2008.

Visits to other Institutes:

1. Kinki University, Fukuoka, Japan, October 2007.
2. Nagoya University, Nagoya, Japan, October 2007.
3. Waseda University, Tokyo, Japan, October 2007.
4. Hong Kong University, Hong Kong, Hong Kong, March 2008.
5. Weinan Teacher's University, Weinan, China, March 2008.

Invited Lectures/Seminars:

1. *On the ABC Conjecture*, Mathematics and Applications - Recent Trends, Burdwan University, Burdwan, January 2008.
2. *Modular forms which behave like theta series*, Kinki University Number Theory Seminar, Kinki University, Fukuoka, October 2007.
3. *Exponents of class groups of real quadratic fields*, Nagoya University Number Theory seminar, Nagoya University, Nagoya, October 2007.
4. *Modular forms which behave like theta series*, Waseda University Number theory Seminar, Waseda University, Tokyo, October 2007.
5. *Modular forms which behave like theta series*, Fourth Northwest Number Theory Conference, North West University, Shengyang, March 2008.
6. *Exponents of class groups of real quadratic fields*, Hong Kong University Number Theory Seminar, Hong Kong University, Hong Kong March 2008.

Other Activities:

1. Organising Committee member of Summer Programme In Mathematics (SPIM). SPIM–2007, June 2007.
2. Coordinator of NBHM Examinations, Co-ordinated M.A./M.Sc. and JRF written tests and interviews, 2007–08.

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Sameer Laxman Chavan

Research Summary:

For unbounded closed left-invertible T, the Cauchy dual operator T' given by

$$T' \equiv T(T^*T)^{-1}$$

provides a bounded unitary invariant. Hence, in some special cases, problems in the theory of unbounded Hilbert space operators can be related to similar problems in the theory of bounded Hilbert space operators. In particular, for a closed expansive T with finite-dimensional co-kernel, it is shown in Preprint 3 that T admits the Cowen-Douglas decomposition if and only if T' admits the Wold-type decomposition. This connection, which is new even in the bounded case (see Preprint 2), enables us to decipher some interesting properties of unbounded 2-hyperexpansions and their Cauchy dual operators such as the completeness of eigenvectors, the hypercyclicity of scalar multiples, and the wandering subspace property.

Publications:

1. S. Chavan, *On Operators Close to Isometries,* Studia Mathematica **186**, 275-293, (2008)

Preprints:

1. S. Chavan, *A Spectral Exclusion Principle for Unbounded Subnormals,* Proceedings of the American Mathematical Society, DOI: 10.1090/S0002-9939-08-09488-4

2. S. Chavan, *Co-analytic, Right Invertible Operators are Supercyclic,* PAMS7942

3. S. Chavan, *On Operators Cauchy Dual to 2-hyperexpansive Operators-II,* AMSTR8213

Invited Lectures/Seminars:

1. *A Friedrichs extension related to unbounded subnormals*, Mathematics Seminar, Harish-Chandra Research Institute, Allahabad, March 2008.

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Chandan Singh Dalawat

Research Summary:
Let p be a prime number. It was shown that for a finite extension K of $\mathbf{Q}_p$ containing a primitive p-th root of unity, the ramification filtration in the upper numbering on the Galois group of the maximal elementary abelian p-extension is orthogonal, under the Kummer pairing, to the filtration by units of various levels on the multiplicative group of K modulo p-th powers. This generalises an earlier result specifying the $\mathbf{F}_p$-line in the group $K^\times/K^{\times p}$ which corresponds to the unramified degree-p extension of K. Applications include a theoretical procedure for computing the relative discriminant of any finite extension of a number field.

Along the way, a direct elementary proof of Serre's mass formula (a weighted count of the number of totally ramified extensions of fixed degree of a given local field) was found in the quadratic case.

Wilson's theorem (the product of all elements in the multiplicative group of $\mathbf{F}_p$ is -1 for every prime p) was extended from $\mathbf{Q}$ to number fields F. The problem consists in finding the product of all units in a finite quotient of the ring of integers of F. There are four possibilities for the said product, and precise conditions are given for each of them to occur. The proof is purely local, and amounts to a cyclicity criterion for the group of units in a finite quotient of the ring of integers of a local field.

Preprints:

1. Chandan Singh Dalawat, *Local discriminants, kummerian extensions, and abelian curves*, 61 pp., arXiv:0711.3878.

2. Chandan Singh Dalawat, *Wilson's theorem*, 5 pp., arXiv:0711.3879.

Conferences/Workshops Attended:

1. *Workshop on Arithmetic Algebraic Geometry*, Mangalore (India), 3–8 June, 2007.

2. *École d'été sur la conjecture de modularité de Serre*, Luminy (France), 8–20 July, 2007.

3. *Galois Representations and Modular Forms*, Chennai Mathematical Institute, Madras (India), 24 September– 5 October, 2007.

4. *Cycles, Motives and Shimura Varieties*, Tata Institute of Fundamental Research, Bombay (India), 3–12 January, 2008.

5. *Arithmetic Geometry*, International Centre for Theoretical Sciences of TIFR, NCBS, Bangalore (India), 23–29 March, 2008.

Visits to other Institutes:

1. Tata Institute of Fundamental Research, Bombay (India), 21 May–5 June, 15–29 June, 2007.
2. Chennai Mathematical Institute, Madras (India) , 25 November–14 December, 2007.

Invited Lectures/Seminars:

1. *Discriminants*, Ramanujan Mathematical Society *Workshop on Arithmetic Algebraic Geometry*, Mangalore, 8 June, 2007 ; Microsoft Research, Bangalore, 11 June, 2007.
2. *Deformation theory* and *Modularity lifting theorems*, two mini-courses at CMI, Madras, September 2007.
3. *Commentaries on Fontaine's lectures*, a set of seven lectures at CMI, Madras, December 2007.
4. *Arithmetic on conics*, a course of six lectures, *Advanced instructional school in Number Theory*, HRI, Allahabad, 17–22 December, 2007.
5. *p-adic numbers*, a course of six lectures, *Annual foundation school*, IIT, Kanpur, 24–29 December, 2007.
6. *Reciprocity laws*, two lectures, *Refresher course in mathematics*, University of Allahabad, March 2008.
7. *The ramification filtration in local kummerian extensions*, ICTS (TIFR) conference on *Arithmetic Geometry*, Bangalore, 25 March, 2008.

Other Activities:

1. Taught the first-semester graduate course in Topology, August–December 2007.
2. One of the organisers the workshop on *Galois Representations and Modular Forms* at CMI, Madras, September 2007.

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Soumya Das

Research Summary:

Working on a problem on estimation of the fourier coefficients of Hermitian modular forms of integer weight for the Hermitian modular group of arbitrary degree over the ring of integers of an imaginary quadratic field. Let K be a imaginary quadratic field, O it's ring of integers. The Hermitian modular group Γ_g of degree g over O is the group of 2g $\times$ 2g complex matrices with entries from O, satisfying

$$\bar{M}' J M = J, \text{ where } J = \begin{pmatrix} 0 & I \\ -I & 0 \end{pmatrix}.$$

A Hermitian cusp form F of weight k for Γ_g is a holomorphic function on the generalized upper half plane $H_g = \{Z \in M(g, \mathbf{C}), \frac{Z-\bar{Z}'}{2i} > 0\}$ and has a fourier expansion of the form :

$$F(Z) = \sum_{T>0} a(T) exp(2\pi i \sigma(TZ)), \text{ where, } T = \bar{T}' \in M(g, \check{O}),$$

where $\check{O}$ = Dual O module w.r.t. the trace form and σ being the trace function. The usual Hecke-bound gives $|a(T)| \leq const.(det(T))^{k/2}$. The problem is to improve this bound; for which we use the Rankin-Selberg method.

Conference/Workshops Attended:

1. *Galois representations and Modular forms*, India, September 24-October 05 , 2007.
2. *Finite Quadratic modules, Weil representations and Applications*, India, February 2008.
3. *AIS in Algebraic and Analytic number theory*, India , 3-28 December, 2007.

Visits to other Institutes:

1. Chennai Mathematical Institute, Chennai, India, September 24 - October 05, 2007.

Invited Lectures/Seminars:

1. *Decomposition, Inertia, Ramification subgroups*, Galois representations and modular forms, Chennai Mathematical Institute, Chennai, September-October, 2007.

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Satya Deo

Research Summary:

During the year 2007-2008, I have been mainly concerned (jointly with M. Baillif and David Gauld) with the study of Mapping Class Groups of some nonmetrizable manifolds. The mapping class groups of the n-fold cartesian product of the ″long ray″ and the ″long plane″ have been completely determined by us-these turn out to be either the symmetric group S_n on n symbols or the extension of these symmetric groups by the order two-groups. Then we construct a large number of other nonmetrizable manifolds using the ideas from graphs, digraphs, attaching of spaces etc, and compute the mapping class groups of these resulting manifolds. We are able to realize every countable group as the mapping class group of a manifold obtained from above constructions. Some uncountable groups have also been proved to be the mapping class groups of above spaces. Our work is in progress.

I am also keeping in touch (jointly with my Ph.D. students) with the developments taking place in areas of my earlier interest viz. homology of group actions, cohomological dimension theory and splines modules.

Publications:

1. Deo, Satya and Maitra, J.K., *Freeness of spline module from a divided domain to a subdivided domain*, Frontiers in interpolation and approximation 59-73, Pure and Appl Math, Chapman and Hill/CRC, Baton Rouge, FL, 2007.

Preprints:

1. M.Baillif, S.Deo and D.Gauld *Mapping class groups of some nonmetrizable manifolds*.

2. Deo, Satya *On eventually constant spaces*.

3. Deo, Satya *Why do we call them projective spaces?*

Conference/Workshops Attended:

1. *Spring Lecture Series*, Department of Mathematics and Statistics University of Arkansas, USA, April 2007.

2. *Annual conference of the Indian Mathematical Society*, University of Poona, Pune, Dec 2007.

Visits to other Institutes:

1. University of Arkansas, USA, April-Dec 2007
2. University of Poona, Pune, Dec 2008
3. University of Allahabad, Allahabad, Feb 2008
4. Ramanjuan Institute of Mathematics, University of Madras, Chennai, March 2008

Invited Lectures/Seminars:

1. Six lectures on *Homology of Group actions*, Topology Seminar, University of Arkansas, USA, April 2007.
2. *Homology and Homotopy of Generalized Hawaiian earrings*, Colloquium Talk, University of Arkansas, USA, Sep 2007.
3. Four lectures on *Search for multiplication in Euclidean n-spaces*, Refresher Course in Mathematics, University of Allahabad, March 2008.
4. Two lectures on *Mapping class groups of some nonmetrizable manifolds*, DSA Programme in Mathematics, Ramanujan Institute of Mathematics, University of Madras, Chennai, March 2008.

Academic recognition/Awards:

- Continue to work as the Academic Secretary of the Indian Mathematical Society during the year 07-08.
- Valedictory address of the Refresher Course at the Department of Mathematics, University of Allahabad, Allahabad, March 2008.

Other Activities:

1. Planned and Organized the academic programme of the Centenary Year annual conference of the Indian Mathematical Society (73rd conference) at the University of Poona, Pune in Dec 2007.
2. Taught a course on Topology II to the first year students (second semester) of HRI during the session 07-08.

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Rukmini Dey

Research Summary:

I worked out the geometric quantization of a dimensionally reduced modified Seiberg-Witten moduli space.

Publications:

1. Rukmini Dey, *HyperKähler prequantization of the Hitchin systems and Chern-Simons gauge theory with complex gauge group,* Adv. Theor. Math. Phys. **11**, 819-837, (2007)

Preprints:

1. Rukmini Dey, *Geometric prequantization of the modified Seiberg-Witten equations in 2-dimensions , (in preparation)*

Visits to other Institutes:

1. S.N. Bose Center, Kolkata, India, May, 2007.

Invited Lectures/Seminars:

1. *Geometric quantization of the hyperKähler structure of the Hitchin system and the vortex moduli space* , S.N. Bose Center, Kolkata, May, 2007.

Other Activities:

1. Taught a course on Differential Geometry, HRI, January - May, 2008.

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Ioulia Baoulina

Research Summary:

The explicit formulas for the number of solutions to some diagonal equations over finite fields were found. The sequence of positive integers with a certain nondivisibility property was studied.

Publications:

1. Ioulia Baoulina, *On the equation* $x_1^{m_1} + \cdots + x_n^{m_n} = ax_1 \cdots x_n$ *over a finite field,* Finite Fields Appl. **13**, 887-895, (2007).

Preprints:

1. Ioulia Baoulina, *On the number of solutions to the equation* $(x_1 + \cdots + x_n)^2 = ax_1 \cdots x_n$ *in a finite field,* Int. J. Number Theory (to appear).

2. Ioulia Baoulina, *On the number of solutions to certain diagonal equations over finite fields,* Int. J. Number Theory (to appear).

3. Ioulia Baoulina and Florian Luca, *On positive integers with a certain nondivisibility property*, Acta Mathematicae et Informaticae (submitted).

4. Ioulia Baoulina, *On the number of solutions of the equation* $(x_1 + \cdots + x_n)^m = ax_1 \cdots x_n$ *over the finite field* $\mathbb{F}_q$ *for* $\gcd(m-n, q-1) = 7$ *and* $\gcd(m-n, q-1) = 14$, (in preparation).

Conference/Workshops Attended:

1. *Conference on 'Perspectives in Mathematical Sciences'*, India, February, 2008.

2. *Workshop on 'Arithmetic Geometry'*, India, March, 2008.

Visits to other Institutes:

1. Panjab University, Chandigarh, India, February-March, 2008.

2. Guru Nanak Dev University, Amritsar, India, March, 2008.

Invited Lectures/Seminars:

1. *On diagonal equations over finite fields*, Chandigarh Symposium in Mathematics, Panjab University, Chandigarh, February-March, 2008.

Other Activities:

1. Reviewer in Mathematical Reviews, August, 2007-March, 2008.
2. Referee in Finite Fields and Their Applications, February-March, 2008.

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Archana Subhash Morye

Research Summery:

I have been working with Prof. N. Raghavendra on a problem related to vector bundles on locally ringed spaces. It is a well-known theorem due to Serre that for an affine scheme $(X, \mathcal{O}_X)$, there is an equivalence of categories between locally free $\mathcal{O}_X$-modules of bounded rank (i.e., vector bundles) and finitely generated projective $\Gamma(X, \mathcal{O}_X)$-modules. Later Swan proved a similar equivalence for a ringed space $(X, \mathcal{O}_X)$, when X is a paracompact topological space of finite covering dimension and $\mathcal{O}_X$ is a sheaf of continuous real valued functions on X. We have been interested in unifying the proof of Serre's Theorem and Swan's Theorem. We say that the *Serre-Swan Theorem holds* for the ringed space $(X, \mathcal{O}_X)$, if there is an equivalence of categories between locally free $\mathcal{O}_X$-modules of bounded rank and finitely generated projective $\Gamma(X, \mathcal{O}_X)$-modules. We proved that Serre-Swan Theorem holds for the locally ringed spaces having some special properties. In particular, connected Stein spaces of bounded dimension, affine differentiable spaces, commutative compact ringed spaces satisfy the required properties and therefore, as a consequence of the above result, Serre-Swan Theorem holds for these ringed spaces.

Preprints:

1. Archana S. Morye, *A Note on the Serre-Swan Theorem* (in preparation)

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Tanusree Pal

Research Summary:

In the academic year "2007-2008", I have worked on the following topics:

1. *$\mathcal{A}_{ff}$-Vogan Diagrams of Twisted Affine Kac-Moody Algebras.* An affine Vogan (abbreviation $\mathcal{A}_{ff}$ -Vogan) diagram is a Dynkin diagram of a Kac-Moody Lie algebra of finite or affine type overlayed with additional structures. In the paper "Classification des formes rélles presque compactes des algébres de Kac Moody affines, Journal of Algebra 267 (2003), H. Ben Messaoud and G. Rousseau gave a classification of almost compact real forms of the affine Kac-Moody algebras. In a series of two papers P. Batra showed that there exists a bijective correspondence between the "equivalence classes" of Vogan diagrams of non-twisted Kac -Moody algebras and the isomorphism classes of their almost compact real forms. In the paper "Affine Vogan Diagrams of Twisted Affine KacMoody Algebras," we modify the definition of Vogan diagrams for the twisted affine Kac-Moody Lie algebras. The modified diagrams are called the $\mathcal{A}_{ff}$-Vogan diagrams. The theory of $\mathcal{A}_{ff}$ -Vogan diagrams for almost compact real forms of indecomposable twisted affine Kac-Moody Lie algebras is then developed and it is shown that there exists a bijective correspondence between the $\mathcal{A}_{ff}$-Vogan diagrams and the almost compact real forms of the twisted Kac-Moody algebras.

2. *Weyl Modules for Double Loop Lie Algebras*. Let $\mathfrak{g}$ be a simple finite dimensional Lie algebra. Let $A := \mathbf{C}[t_1^{\pm 1}, t_2^{\pm 1}]$ be the Laurent polynomial ring in two commuting variables. Then $\mathfrak{g}_A := \mathfrak{g} \otimes A$ is defined to be a double loop Lie algebra. In the paper, "Weyl Modules for Classical and Quantum affine algebras, Representation Theory, 5 (2001)," V. Chari and A. Pressley, studied the Weyl modules for the Lie algebras $L(\mathfrak{g}) := \mathfrak{g} \otimes \mathbf{C}[t^{\pm}]$ and they showed that any finite dimensional highest weight $L(\mathfrak{g})$-module V whose highest weight space is one dimensional is a quotient of a Weyl module.

   In a joint project with V. Chari and G. Fourier, we are developing the theory of Weyl modules for the double loop Lie algebras. Some work in this respect has been done by B. Feigin and S. Loktev in the paper "Multi-dimensional Weyl Modules and Symmetric Functions, Communications in Mathematical Physics,251 (2004)." Our study of the Weyl modules adopts a different approach through explicit generators and relations, thereby simplifying the study of the Weyl modules for the corresponding twisted multi-loop Lie algebras as defined by B. Allison, S. Berman, J. Faulkner and A. Pianzola in "Realization of graded-simple algebras as loop algebras."

Preprints:

1. Tanusree Pal and Punita Batra, Representation of Graded Multiloop Lie Algebra, submitted.
2. Tanusree Pal, Affine Vogan Diagrams of Twisted Affine KacMoody Algebras, submitted.

Conference/Workshops Attended:

1. AIS Representation Theory and its Applications, India, July 2007.

Other Activities:

1. Tutor for Algebra course taught in SPIM, June, 2007.

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Supriya Pisolkar

Research Summary:

This year I finished working on the following two problems.

1. The absolute norm of a p-primary unit: Let K be a p-adic fields containing a primitive p^m-th root of unity. A unit $u \in \mathrm{K}$ is called p-primary if the extension $\mathrm{K}(\mathrm{u}^{1/\mathrm{p}})/\mathrm{K}$ is an unramified extension. We proved a local analogue of J. Martinet's theorem about the absolute norm of the relative discriminant ideal of an extension of number fields L/K. This turns out to be a statement about a two primary unit. In fact, we generalise a similar result for all primes p. We also recover Martinet's theorem using our local result in the special case when L has an integral basis.

2. Chow group of zero cycles of degree zero of certain $Châtelet$ surfaces over local fields: By using the theory of Hilbert Symbols over a 2-adic field, we have been able to simplify a lot of calculations of this paper. Also we have added a global result.

I attended a course by Prof. Fontaine on p-adic galois representation theory. I continued reading the theory of ϕ - Γ-modules under the guidance of Prof. C. S. Rajan during my academic visit to TIFR.

Preprints:

1. Supriya Pisolkar, *Absolute norm of a p-primary unit* (in preparation)

2. Supriya Pisolkar, *Chow group of zero cycles of degree zero of certain $Châtelet$ surfaces over local fields* (in preparation)

Conference/Workshops Attended:

1. *A workshop on Galois representation theory and Serre's conjecture*, Chennai Mathematical Institute, Chennai; September, 2007.

2. *Lecture series on p-adic Galois representation theory*, Chennai Mathematical Institute, Chennai; November, 2007.

3. *Clay lecture series in mathematics*, Tata Institute oF Fundamental Research, Mumbai; January, 2008.

4. *A conference on Motives and arithmetic of Shimura varieties*, Tata Institute oF Fundamental Research, Mumbai; January, 2008.

Visits to other Institutes:

1. Chennai Mathematical Institute, Chennai, November 24 to December 6 2007.
2. Tata Institute oF Fundamental Research , Mumbai, December 2007 to March 2008.

Invited Lectures/Seminars:

1. *Local fields and ramification groups*, A workshop on Galois representation theory and Serre's conjecture, Chennai Mathematical Institute, Chennai, Sept, 2007.

Other Activities:

1. Conducted tutorials and discussions for two subjects - Number Theory and Galois Theory in SPIM held in June 2007 at HRI.
2. Conducted projects and gave a talk on 'Mathematics in Nature' in KVYP program at HRI in May 2007.

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N. Raghavendra

Research Summary:

Have been working on questions related to the Serre-Swan theorem and generalizations of the Atiyah class.

Other Activities:

1. Taught the first year graduate course *Algebra II*, second semester, 2007–08.
2. Was the convener of the Mathematics Graduate Studies Committee, and a member of the SYM (Special Years in Mathematics) Coordination Committee.
3. Was a member of the Board of Studies in Mathematics, Homi Bhabha National Institute (HBNI).

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Ramakrishnan B.

Research Summary:

1. Let

$$\Delta(z) = q\prod_{n\geq 1}(1-q^n)^{24} = \sum_{n\geq 1}\tau(n)q^n$$

be the Ramanujan's cusp form of weight 12 for $SL_2(\mathbf{Z})$, where $q = e^{2\pi iz}$, z belongs to the upper half-plane $\mathcal{H}$. The function $\tau(n)$ is called the Ramanujan's tau-function. Using differential equations satisfied by $\Delta(z)$, B. van der Pol derived identities relating $\tau(n)$ to sum-of-divisors functions. For example,

$$\tau(n) = n^2\sigma_3(n) + 60\sum_{m=1}^{n-1}(2n-3m)(n-3m)\sigma_3(m)\sigma_3(n-m), \tag{1}$$

where $\sigma_k(n) = \sum_{d|n} d^k$. Using the relation between $\sigma_3(n)$ and $\sigma_7(n)$ this is equivalent to the following identity:

$$\tau(n) = n^2\sigma_7(n) - 540\sum_{m=1}^{n-1} m(n-m)\sigma_3(m)\sigma_3(n-m). \tag{2}$$

In 2004, D. Lanphier used differential operators studied by H. Maass to prove the above van der Pol identity (2). He also obtained several van der Pol-type identities using the Maass operators and thereby obtained new congruences for the Ramanujan's tau-function. In 1975, D. Niebur derived a formula for $\tau(n)$ similar to the classical ones of Ramanujan and van der Pol, but has the feature that higher divisor sums do not appear. Niebur proved the formula by expressing $\Delta(z)$ in terms of the logarithmic derivatives of $\Delta(z)$.

In this work, we show that the identities for the Ramanujan function $\tau(n)$ proved by Lanphier can be obtained using the Rankin-Cohen bracket for modular forms and the basic relations among the Eisenstein series. By our method we also obtain new identities for $\tau(n)$ which are not proved by Lanphier. Next we show that the theory of quasimodular forms can be used to prove Niebur's formula for $\tau(n)$. The method of using quasimodular forms gives new formulas for $\tau(n)$. We observe that the identities of $\tau(n)$ give rise to various identities for the convolution of the divisor functions. As a consequence, we also present some congruences involving the divisor functions. This is a joint work with B. Sahu.

2. We study the twisted averages of L-functions of cusp forms of half-integral weight. For a non-zero cusp form of weight $k+1/2$ on $\Gamma_0(4N)$, which is a Hecke

eigenform, we show that the second moment of the twisted L-function at the center of the critical stip averaged over the twisted characters modulo a prime ℓ, $(\ell, 2N) = 1$, is (up to a constant depending on k and N) bounded by $\varphi(\ell)$. It is expected that these results imply that a positive proportion of these twisted L-functions do not vanish. This is a joint work with M. Manickam and V. Kumar Murty and the work is in progress.

Publications:

1. S. Gun and B. Ramakrishnan, *On special values of certain Dirichlet L-functions,* The Ramanujan Journal **15**, 275–280, (2008)

Preprints:

1. B. Ramakrishnan and Brundaban Sahu, *Rankin-Cohen Brackets and van der Pol-Type Identities for the Ramanujan's Tau Function.*

Conference/Workshops Attended:

1. *Arithmetic Geometry*, India, March 2008.

Visits to other Institutes:

1. University of Toronto, Mississauga, Canada, May 2007.

Invited Lectures/Seminars:

1. *Rankin's method and Jacobi forms*, Number Theory Seminar, Queen's University, Kingston, Canada, June 2007.

Other Activities:

1. Guiding three students for their Ph.D, one of them will be submitting his thesis in April 2008.
2. Organized the visit of Prof. N. -P. Skoruppa, University of Siegen at HRI under the SYM project during Feb 2008.
3. Dean of Administration (since October 2005).

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Ratnakumar Peetta Kandy

Research Summary:

For the last few months, I have been working on some analyticity questions for the solutions of the Schroedinger equation on the Heisenberg group. This is a joint work with Prof. S. Thangavelu and Sanjay Parui, where we also consider Schroedinger equations for certain operators, generalising the Heisenberg sub-laplacian. This work is almost complete and a preprint is in preparation.

I was also working on improving an old unpublished work regarding the L^p mapping property of spherical maximal operator on n dimensional Euclidean space, and also looking at some related weighted norm estimate in for the spherical maximal operator.

Publications:

1. P. K. Ratnakumar, *On Schrödinger propagator for the special Hermite operator, J. Fourier Anal. and Appl.,* Journal name **Vol 14, No. 2**, 286-300, (2008)

Preprints:

1. S. Parui, P.K. Ratnakumar, S. Thangavelu, *Schrödinger equation on the Heisenberg group, Analytic extension,* (in preparation)

Conference/Workshops Attended:

1. *Workshop on Harmonic Analysis and Partial Differential Equations, Mexico, February, 2008.*

2. *10th Discussion meeting on Harmonic Analysis, India, December 2007.*

Visits to other Institutes:

1. Indian Institute of Science, Bangalore, India, June 2007.

2. Indian Institute of Technology, Kanpur, India, March 2008.

Invited Lectures/Seminars:

1. *"Schrödinger propagator for the special Hermite operator, some regularity questions". Workshop on Harmonic Analysis and Partial Differential Equations, Mexico, February, 2008.*

2. *"Spherical maximal operator on constant curvature spaces", Indian Institute of Technology, Kanpur, India, March 2008.*

Other Activities:

1. Organised Summer Programme in Mathematics, (SPIM 2007), June, 2007.

2. Gave a set of 10 lectures in Differential Geometry, in SPIM 2007.

3. Taught the course Real Analysis, for the first semester Ph. D. students for the year 2007-2008.

4. Gave a special course on Harmonic Analysis, during second semester.

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Brundaban Sahu

Research Summary:

A modular form has a Fourier expansion and the Fourier coefficients determine the modular form. Hence the study of properties of the Fourier coefficients of modular forms is very useful. For example, let

$$\Delta(z) = q\prod_{n\geq 1}(1-q^n)^{24} = \sum_{n\geq 1}\tau(n)q^n$$

be the Ramanujan's cusp form of weight 12 for $SL_2(\mathbb{Z})$, where $q = e^{2\pi iz}$, z belongs to the complex upper half-plane $\mathcal{H}$. The function $\tau(n)$ is called the Ramanujan tau-function. S. Ramanujan made following conjectures about $\tau(n)$:

1. $\tau(mn) = \tau(m)\tau(n)$ if $\gcd(m,n) = 1$.
2. $\tau(p^{n+1}) = \tau(p)\tau(p^n) - p^{11}\tau(p^{n-1}) \quad \forall n \geq 1$, for fixed prime p.
3. $|\tau(n)| \leq n^{11/2}\sigma_0(n)$, where $\sigma_0(n)$ is the number of divisors of n.

The first two identities were proved by L. J. Mordell and the third was proved by P. Deligne as a consequence of his proof of the Weil conjectures. There is another famous conjecture of D. H. Lehmer which says that $\tau(n) \neq 0$ for all n. This conjecture is still open, though many important results have been obtained towards proving this conjecture. So, the study of identities and congruences relating $\tau(n)$ is still an interesting problem.

Using differential equations satisfied by $\Delta(z)$, B. van der Pol derived identities relating $\tau(n)$ to sum-of-divisors functions. For example,

$$\tau(n) = n^2\sigma_3(n) + 60\sum_{m=1}^{n-1}(2n-3m)(n-3m)\sigma_3(m)\sigma_3(n-m),$$

where $\sigma_k(n) = \sum_{d|n} d^k$. Using the known relation between $\sigma_3(n)$ and $\sigma_7(n)$ this is equivalent to the following identity:

$$\tau(n) = n^2\sigma_7(n) - 540\sum_{m=1}^{n-1} m(n-m)\sigma_3(m)\sigma_3(n-m).$$

D. Lanphier used differential operators studied by H. Maass to prove the above van der Pol's identity. He also obtained several van der Pol-type identities using

the Maass operators and thereby obtained new congruences for the Ramanujan tau-function. D. Niebur derived a formula for $\tau(n)$ similar to the classical ones of Ramanujan and van der Pol, but has the feature that higher divisor sums do not appear. Niebur proved the formula by expressing $\Delta(z)$ in terms of the logarithmic derivatives of $\Delta(z)$.

We show that the identities for the Ramanujan function $\tau(n)$ proved by Lanphier can be obtained using the Rankin-Cohen brackets for modular forms and the basic relations among the Eisenstein series. Further, we use the theory of quasimodular forms and the Rankin-Cohen brackets of quasimodular forms to prove Niebur's formula for $\tau(n)$. Our method of using Rankin-Cohen brackets and the quasimodular forms give rise to new formulas for $\tau(n)$, which are different from the ones obtained by Lanphier and Niebur. Though in principle one can obtain many identities for $\tau(n)$ using our method, here we restrict only to those identities in which only the convolution of divisor functions appear. We observe that these identities of $\tau(n)$ give rise to various identities for the convolution of the divisor functions. As a consequence, we also present some congruences involving the divisor functions.

Publications:

1. (with S. Gun, Florian Luca, P. Rath, R. Thangadurai) *Distribution of Residues Modulo p,* Acta Arith. **129**, no. 4, 325–333, (2007).

Preprints:

1. (with B. Ramakrishnan) *Rankin-Cohen Brackets and van der Pol-Type Identities for the Ramanujan's Tau Function*, arXiv:0711.3512v1 [math.NT] (Submitted for Publication).

2. (with B. Ramakrishnan) *Rankin's method and Jacobi forms of several variables* (Submitted for Publication).

Conferences/Workshops Attended:

1. *School and Conference on Analytic Number Theory*, ICTP, Italy, (April 23-May 06, 2007).

2. *Jacobi Forms and Applications*, CIRM, Luminy, France, (May 7-11, 2007).

3. *Workshop on Arithmetic Geometry*, Chennai Mathematical Institute, Chennai, India, (Sept 24-Oct 05, 2007).

4. *Advanced Instructional School in Analytic and Algebraic Number Theory*, HRI, Allahabad, India, (Dec 3-28, 2007).

5. *International Colloquium on Cycles, Motives and Shimura Varieties*, TIFR, Mumbai, India, (Jan 3-12, 2008).

Visits to other Institutes:

1. Institute of Mathematics and Applications, Bhaubaneswar, India (June 1-15, 2007).

2. The Institute of Mathematical Sciences, Chennai, India (29th Feb - 11th March, 2008).

Invited Lectures/Seminars:

1. *On the Rankin-Cohen Brackets for Jacobi Forms of higher degree*, Jacobi Forms and Applications, CIRM, Luminy, France, (May 7-11, 2007).

2. *Group Theory, a series of ten lectures*, Interactive Mathematics Training Camp, Regional Institute of Education, Bhubaneswar, (sponsored by NBHM), organized by Institute of Mathematics and Applications, Bhubaneswar (June 2007).

3. *Basic Topology, a series of ten lectures* Interactive Mathematics Training Camp, Regional Institute of Education, Bhubaneswar, (sponsored by NBHM), organized by Institute of Mathematics and Applications, Bhubaneswar (June 2007).

4. *Hilbert Modular Forms*, Workshop on Arithmetic Geometry, Chennai Mathematical Institute, Chennai, India, (Sept 24-Oct 05, 2007).

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Mahender Singh

Research Summary:

During the academic year 2007 -2008, I have been working mainly on compact transformation groups. Particularly, I have been investigating relations between the structure of the cohomology algebra of a space, its orbit space and its fixed point set under actions of compact Lie groups using techniques of spectral sequences. I studied $\mathbb{S}^1$ actions on cell complexes X whose rational cohomology is isomorphic to that of the wedge sum $P^2(n) \vee \mathbb{S}^{3n}$ or $\mathbb{S}^n \vee \mathbb{S}^{2n} \vee \mathbb{S}^{3n}$ and determined completely the possible fixed point sets upto rational cohomology, depending on whether or not X is totally non-homologous to zero in $X_{\mathbb{S}^1}$ in the Borel fibration $X \hookrightarrow X_{\mathbb{S}^1} \longrightarrow B_{\mathbb{S}^1}$. Similar study was done for involutions and the fixed point sets were determined upto mod-2 cohomology. I also investigated free involutions on lens spaces. The possible cohomology algebra of orbit space of any free involution on a mod-2 cohomology lens space X was determined using the Leray spectral sequence associated to the Borel fibration $X \hookrightarrow X_{\mathbb{Z}_2} \longrightarrow B_{\mathbb{Z}_2}$ and an application to equivariant maps $\mathbb{S}^n \to X$ was given.

Publications:

1. Mahender Singh, *$\mathbb{Z}_2$ actions on complexes with three non-trivial cells*, Topology and its Applications **155**, 965-971, (2008).

Preprints:

1. Mahender Singh, *Fixed points of circle actions on complexes with three non-trivial cells*, communicated.

2. Mahender Singh, *Cohomology algebra of orbit spaces of free involutions on lens spaces*, preprint.

Conferences/Workshops Attended:

1. *Workshop and Conference in Geometry and Topology*, IIT Bombay, India, August 17-26, 2007.

2. *Workshop in Algebraic Topology*, IMSc Chennai, India, June 04-09, 2007.

Other Activities:

1. I took tutorials in Differential Geometry course in Summer Programme in Mathematics-HRI, June 2007.

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D. Surya Ramana

Research Summary:

It is of interest in the context of inequalities of the large sieve type to obtain estimates for the sum $\sum_{x\in\mathcal{X}} |\sum_{i\in I} a_i e(xf(i))|^2$, where $e(z)$ denotes $e^{2\pi iz}$ for any complex number z, $\mathcal{X}$ is a well-spaced sequence of real numbers, I is an interval of the integers , $\{a_i\}_{i\in I}$ are complex numbers and f is real valued function on I such that $f(I)$ is sparse, that is, the length of $f(I)$ is "much larger" than that of I.

Basic examples of functions f for which $f(I)$ is sparse are polynomials of degree ≥ 2. Iwaniec and Kowalski have posed the question of determining good large sieve bounds when f is $P(T)$, a given polynomial in $\mathbf{Z}[T]$, and $\mathcal{X}$ is $\mathcal{F}(Q)$, the Farey sequence of order Q, where Q is a real number ≥ 1. In the preprint *Large Sieve Inequality for Integer Polynomial Amplitudes*, authored with Dr. Gyan Prakash, we obtain an essentially best possible answer to this question, thereby improving upon and generalising the results of L. Zhao, S. Baier and O. Ramaré on this question.

In a companion article to the preprint described above titled *Large Sieve Inequality for Quadratic Polynomial Amplitudes*, also with Dr. Gyan Prakash, we consider the large sieve inequality with amplitudes this time given by quadratic polynomials with real coefficients. Combining our method in the integer polynomials case with a device of L. Zhao and another of S. Baier's, we improve upon their results for quadratic polynomials with real coefficients, as also our own earlier result on this question, which was described in a preprint with the same title in report for 2006-2007.

Finally, in the preprint titled *Arcs with no more than Two Integer Points on Conics* we bring to a close work completed partially last year and described in the last report as the content of a preprint titled *Arcs with Three Integer Points on Conics*. More precisely, in the present preprint we show that when a, d and R are integers distinct from 0 and a and d are coprime, there are no more than 2 integer points on an arc of length $\leq 2\left(\frac{|ad|m_{ad}^2|R|}{\sup(|a|,|d|)^3}\right)^{1/6}$ on the conic $aX^2+dY^2=R$, where m_{ad} is an integer whose value we give. We then show this conclusion to be the best possible and provide a higher dimensional analogue for $n+1$ integer points on $a_1X_1^2+a_2X_2^2+\ldots+a_nX_n^2=R$, where the a_i, R and $n\geq 2$ are integers. This analogue is also shown to be the best possible. These results generalise earlier results of J. Cilleruelo revisited recently by A. Granville and J. Cilleruelo.

Publications:

1. D.S. Ramana, *Arithmetical Applications of an Identity for the Vandermonde De-*

terminant, Acta Arithmetica **130.4**, 351-359, (2007).

Preprints:

1. D.S. Ramana,*Arcs with no more than Two Integer Points on Conics*,(submitted).
2. Gyan Prakash and D.S. Ramana, *Large Sieve Inequality for Integer Polynomial Amplitudes,* (submitted).
3. Gyan Prakash and D.S. Ramana, *Large Sieve Inequality for Quadratic Polynomial Amplitudes,* (submitted).

Conference/Workshops Attended:

1. DOCCOURSE *in Additive Combinatorics*, Spain, February, 2008.

Visits to other Institutes:

1. Bristol University, Bristol, United Kingdom, September, 2007.
2. Universidad Autonoma Madrid, Madrid, Spain, October, 2007.
3. University of Lille I, Lille, France, October, 2007.
4. University of Paris, Paris, France, October, 2007.

Invited Lectures/Seminars:

1. *Spacing out with Vandermonde*, Heilbronn Seminar, Bristol University, Bristol, October 2007.
2. *Spacing out with Vandermonde*, Daboussi Seminar, University of Paris, Paris, October 2007.
3. *Sumfree subsets of finite Abelian Groups*, Seminar of the Mathematics Department, Universidad Autonoma Madrid, Madrid, October 2007.
4. *Sumfree subsets of finite Abelian Groups*, DOCCOURSE in Additive Combinatorics, Universidad Autonoma Barcelona, Barcelona, March 2008.

Other Activities:

1. Gave a course of 9 lectures on Analytic Number Theory in the Advanced Instructional School in Analytic and Algebraic Number Theory at H.R.I. in December, 2007. Teaching at H.R.I.: Analysis II, January - May, 2008.

2. Served as referee for the Indian J. of Pure and Applied Math. and the Journal of the Ramanujan Math. Soc. (one paper each).

3. Served on the Local Works Committee, H.R.I. for 2007-2008.

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R. Thangadurai

Research Summary:

We (with F. Luca and I. E. Sparlinski) have improved the earlier result on the distribution of quadratic non-residues which are not primitive roots modulo p which is published in Journal of RMS this year. In the collected works of S. S. Pillai, two volumes were completed. Major part of this year 2007 went in finalizing the first two volumes of this collected works.

Inspiring by S. S. Pillai, two problems which were started by him, were studied with the collaboration of F. Luca and N. Saradha respectively.

In another direction, we studied the problem of number of prime factors of a product of m consecutive integers. We proved that a folklore conjecture in this direction is true, if one assumes Schnizel's H hypothesis.

Publications:

1. S. Gun, F. Luca, P. Rath, B. Sahu and R. Thangadurai, *Distribution of residues modulo p*. Acta Arith. 129 (2007), no. 4, 325–333.

2. R. Thangadurai, *Irreducibility of polynomials whose coefficients are integers*. RMS Math. Newsletter 17 (2007), no. 2, 29-37.

3. P. Rath, K. Srilakshmi and R. Thangadurai, *On Davenport's constant*, Int. J. Number Theory, **4**, No. 1 (2008) 107-115.

4. W. D. Gao, R. Thangadurai, J. Zhuang, *Addition theorems on the cyclic groups of order p^ℓ*, Discrete Math. **308** (2008) 2030-2033.

5. F. Luca, I. E. Shparlinski and R. Thangadurai, *Quadratic non-residues verses primitive roots mod p*, Journal of Ramanujan Mathematical Society, **23**, No. 1, (2008), 97-104.

Preprints:

1. F. Luca and R. Thangadurai, *On a paper of Pillai*, Submitted for Publication.

2. R. Balasubramanian, S. Laishram, T. N. Shorey and R. Thangadurai, *The number of prime divisors of the product of consecutive integers*, Submitted for Publication.

3. N. Saradha and R. Thangadurai, *Pillai's problem on consecutive integers*, Submitted for Publication.

Conference/Workshops Attended:

1. Attended a workshop on "Analytic Number Theory" at ICTP, Trieste, Italy from 23rd April to 12th May, 2007.
2. Done tutorials for the AIS on 'Analytic Number Theory' at HRI, Allahabad in December, 2007.
3. Delivered a lecture in a conference on "Algebra, Number Theory and Cryptography" at University of Calcutta, Kolkata from 25-27th March, 2008.

Visits to other Institutes:

1. ICTP, Trieste, Italy from 23rd April to 12th May, 2007.
2. University of Graz, Graz, Austria, April, 2007.
3. Tata Institute of Fundamental Research, Mumbai in August-September, 2007.
4. Institute of Mathematical Sciences, Chennai in September, 2007 and February, 2008.
5. University of Poona, Pune and Bhaskaracharya Pratishthana, Pune in February, 2008.
6. University of Calcutta, Kolkata in March, 2008.

Invited Lectures/Seminars:

1. '*Distribution of residues modulo p*' at Mathematics and Scientific Computing, University of Graz, Austria in April, 2007.
2. '*Quadratic non-residues; but not primitive roots modulo p*' at Tata Institute of Fundamental Research, Mumbai in September, 2007.
3. Gave a course on '*Elementary Number Theory* in MTTS 2007 for Level '0' students in May-June, 2007.
4. '*On a problem of S. S. Pillai*' at University of Poona, Pune in February, 2008.
5. '*Mathematical and Non-Mathematical Life of S. S. Pillai*' at University of Poona, Pune in February, 2008.
6. '*On a problem of S. S. Pillai*' at University of Calcutta, Kolkata in March, 2008.

Other Activities:

1. Member of the Interview board for KVPY fellowships for the year 2008.
2. Member of the selection board of 'Hindi Typist post' in 2008.
3. Office Furniture Committee, member, 2007-08.
4. Library Committee, Member, 2007-08.

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Manoj Kumar (Yadav)

Research Summary:

Let G be a finite p-group of nilpotency class 2. An automorphism α of G is called central if $x^{-1}\alpha(x) \in Z(G)$ for all $x \in G$, where $Z(G)$ denotes the center of G. We find necessary and sufficient conditions on G such that each central automorphism of G fixes $Z(G)$ element-wise.

We also started working on the following classification problem: Classify all finite p-groups of nilpotency class 2 such that every automorphism of G preserves the conjugacy classes of G. We have some partial result in this direction.

Publications:

1. Manoj K. Yadav, *Class preserving automorphisms of finite p-groups,* J. London Math. Soc. **75**, 755-772, (2007)

2. Manoj K. Yadav, *On automorphisms of finite p-groups,* J. Group Theory **10**, 859-866, (2007)

3. Manoj K. Yadav, *On automorphisms of some finite p-groups,* Proc. Indian Acad. Sci. (Math. Sci.) **118**, 1-11, (2008)

Preprints:

1. Manoj K. Yadav, *On central automorphisms fixing the center element-wise* http://arxiv.org/abs/0803.4081v1/

2. Manoj K. Yadav, *On automorphisms of finite p-groups of class 2,* (in preparation)

Conference/Workshops Attended:

1. *Annual conference of Indian Mathematical Society*, INDIA, December 2007.

Invited Lectures/Seminars:

1. *Automorphisms of finite p-groups*, Chandigarh symposium, Department of Mathematics, Panjab University, Chandigarh, February 2008.

2. *Automorphisms of finite groups and their applications to cryptography*, Silver jubilee M. Phil. programme, Department of Mathematics, Dr. B. R. Ambedkar University, Agra, October 2007.

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ACADEMIC REPORT - PHYSICS

Sanjib Kumar Agarwalla

Research Summary:

Our work is mainly focused on the precision measurements of the neutrino oscillation parameters mainly the issue of neutrino mass ordering and θ_{13} in the planned/proposed next generation long baseline neutrino experiments like Beta Beam, Neutrino factory. In this context, we show that the earth matter effects in the $\nu_{\rm e} \to \nu_{\rm e}$ survival probability can be used to cleanly determine the third leptonic mixing angle θ_{13} and the sign of the atmospheric neutrino mass squared difference, Δm^2_{31}, using a β-beam as a ν_e source.

We also expound in detail the physics reach of an experimental set-up in which the proposed large magnetized iron detector at the India-based Neutrino Observatory (INO) would serve as the far detector for a so-called beta-beam. If this pure ν_e and/or $\bar{\nu}_e$ beam is shot from some source location like CERN such that the source-detector distance $L \simeq 7500$ km, the impact of the CP phase δ_{CP} on the oscillation probability and associated parameter correlation and degeneracies are almost negligible. This "magical" beta-beam experiment would have unprecedented sensitivity to the neutrino mass hierarchy and θ_{13}, two of the missing ingredients needed for our understanding of the neutrino sector. With Lorentz boost $\gamma = 650$ and irrespective of the true value of δ_{CP}, the neutrino mass hierarchy could be determined at 3σ C.L. if $\sin^2 2\theta_{13}(\text{true}) > 5.6 \times 10^{-4}$ and we can expect an unambiguous signal for θ_{13} at 3σ C.L. if $\sin^2 2\theta_{13}(\text{true}) > 5.1 \times 10^{-4}$ independent of the true neutrino mass hierarchy.

In an another work, we perform a comprehensive and detailed comparison of the physics reach of beta-beam neutrino experiments between two pairs of plausible source ions, (^{8}B, ^{8}Li) and (^{18}Ne, ^{6}He). We study the optimal choices for the baseline, boost factor, and luminosity. We take a 50 kton iron calorimeter, *a la* ICAL@INO, as the far detector. We follow two complementary approaches for our study: (i) Fixing the number of useful ion decays and boost factor of the beam, and optimizing for the sensitivity reach between the two pairs of ions as a function of the baseline. (ii) Matching the shape of the spectrum between the two pairs of ions, and studying the requirements for baseline, boost factor, and luminosity. We find that for each pair of ions there are two baselines with very good sensitivity reaches: a short baseline with $L\,[\text{km}]/\gamma \simeq 2.6$ (^{8}B+^{8}Li) and $L\,[\text{km}]/\gamma \simeq 0.8$ (^{18}Ne+^{6}He), and a long "magic" baseline. For $\gamma \sim 500$, one would optimally use ^{18}Ne and ^{6}He at the short baseline for CP violation, ^{8}B and ^{8}Li at

the magic baseline for the mass hierarchy, and either ^{18}Ne and ^{6}He at the short baseline or ^{8}B and ^{8}Li at the magic baseline for the $\sin^2 2\theta_{13}$ discovery.

Publications:

1. Sanjib Kumar Agarwalla, Sandhya Choubey, Srubabati Goswami, Amitava Raychaudhuri, *Neutrino parameters from matter effects in P_{ee} at long baselines,* Phys.Rev.D **75**, 097302, (2007)

2. Sanjib Kumar Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, *Unraveling neutrino parameters with a magical beta-beam experiment at INO,* Nuclear Physics B **798**, 124-145, (2008)

Preprints:

1. Sanjib Kumar Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, Walter Winter, *Optimizing the greenfield Beta-beam,* arXiv:0802.3621 [hep-ex].

Conference/Workshops Attended:

1. *Summer School on Particle Physics*, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy, 11th to 22nd June, 2007.

2. *6th International School on Neutrino Factories, Super Beams and Beta Beams*, KEK, Tsukuba, Japan, July 27 - August 4, 2007.

3. *Ninth International Workshop on Neutrino Factories, Super Beams and Beta Beams (NuFact07)*, Okayama University, Okayama, Japan, August 6-11, 2007.

4. *Xth Workshop on High Energy Physics Phenomenology (WHEPP-X)*, IMSc, Chennai, India, 2nd to 13th January, 08.

5. *Nu HoRIzons*, HRI, Allahabad, India, February, 08.

6. *Diamond Jubilee Seminar on Current Trends in Physics*, Panjab University, Chandigarh, India, February, 08.

Visits to other Institutes:

1. MPI-K, Heidelberg, Germany, May, 2007.

2. University of Wurzburg, Wurzburg, Germany, May, 2007.

3. Max-Planck-Institute for Physics, Munich, Germany, May, 2007.

4. ICTP, Trieste, Italy, June, 2007.

5. INFN, Padova, Italy, June, 2007.

Invited Lectures/Seminars:

1. *Magic Baseline Beta Beam*, MPI-K Seminar, MPI-K, Heidelberg, Germany, 21st May, 2007.

2. *The India-based Neutrino Observatory : Present Status and Physics Prospects*, University of Wurzburg Weekly Seminar, University of Wurzburg, Wurzburg, Germany, 24th May, 2007.

3. *Magic Baseline Beta Beam*, Max-Planck-Institute for Physics, Munich Weekly Seminar, Max-Planck-Institute for Physics, Munich, Germany, 29th May, 2007.

4. *Magic Baseline Beta Beam*, ICTP Weekly Seminar, ICTP, Trieste, Italy, 26th June, 2007.

5. *Magic Baseline Beta Beam*, INFN, Padova Weekly Seminar, INFN, Padova, Italy, 28th June, 2007.

6. *New Physics Searches with Beta Beams*, NuFact 07 Conference, Okayama University, Okayama, Japan, 8th August, 2007.

7. *Some aspects of neutrino mixing and oscillations*, Pre-Ph.D. Seminar, Calcutta University, Kolkata, India, 10th September, 2007.

8. *Physics Potential of Long Baseline Experiments*, WHEPP-X, IMSc, Chennai, India, 5th January, 2008.

9. *Long range forces in long baseline experiments*, NuHoRIzons 2008 conference, HRI, Allahabad, India, 14th February, 2008.

10. *Prospects of INO with Neutrino Beams*, Diamond Jubilee Seminar on Current Trends in Physics, Panjab University, Chandigarh, India, 29th February, 2008.

Academic recognition/Awards:

- Best student award of Nufact 07 summer school at KEK, Tsukuba, Japan, 2007.

- Post-Doctoral position for the session October,2008-September,2009 at Virginia Polytechnic Institute & State University.

Other Activities:

1. Pheno lunch review talks and extension talk.
2. Lecture given at Rajbhasa Programme.

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Arjun Bagchi

Research Summary:

Over the past year, along with my supervisor, Ashoke Sen, I have been working on Superstring field theory. We have analyzed several aspects of a system of separated brane-antibrane systems using level truncation and conformal field theory techniqu es.

Recently, again with Ashoke Sen, I have started looking at tachyons on hairpin branes with possible applications in AdS-CFT in mind.

With Turbasu Biswas and Debashis Ghoshal, I am also studying logarithmic conformal field theories. We are looking to find integral representations to modified characters in LCFT.

Publications:

1. Arjun Bagchi and Ashoke Sen, *Tachyon Condensation on Separated Brane-Antibrane Systems,* arXiv: 0801.3498 (hep-th) JHEP **0805:010**, (2008)

Conference/Workshops Attended:

1. *ISS07*, IPM, Tehran, Iran, April 2007.
2. *Gauge Fields and Strings*, Isaac Newton Institute, Cambridge, United Kingdom. September 2007.
3. *Indian Strings Meet*, HRI, Allahabad, October 2007.
4. *From Strings to LHC II*, Fireflies Ashram, Bangalore, December 2007.

Visits to other Institutes:

1. Jawaharlal Nehru University, Delhi. April 2008.

Invited Lectures/Seminars:

1. *Sitting and Rolling Tachyons on Separated Branes (Short Presentation)*, Isaac Newton Institute for Mathematical Sciences, Cambridge, U.K., September 2008..

Other Activities:

1. Organised and conducted a science quiz for KVPY students, May 2007.

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Jasjeet Singh Bagla

Research Summary:

Homogeneity and isotropy of the universe at *sufficiently* large scales is a fundamental premise on which modern cosmology is based. Fractal dimensions of matter distribution is a parameter that can be used to test the hypothesis of homogeneity. In this method, galaxies are used as tracers of the distribution of matter and samples derived from various galaxy redshift surveys have been used to determine the scale of homogeneity in the Universe. Ideally, for homogeneity, the distribution should have the fractal dimension equal to 3, the dimensionality of space. While this ideal definition is true for infinitely large point sets, this may not be realized as in practice, we have only a finite point set. We (Bagla, Yadav and Seshadri, 2007) derived the expected fractal dimension for a homogeneous distribution of a finite number of points. This is the appropriate benchmark that should be used in place of the dimension of space D. We also compute the expected fractal dimension for a finite point set that is weakly clustered. Clustering introduces departures in the Fractal dimensions from D and in most situations the departures are small if the amplitude of clustering is small. In our universe, the evolution of perturbations prior to the epoch of matter-radiation decoupling imposes certain features in the amplitude of clustering known as Baryon Acoustic Oscillations (BAO). We show that the presence of such features leads to non-trivial variations in the Fractal dimensions where the amplitude of clustering and deviations from D are no longer related in a monotonic manner. We also propose a method for estimating the scale of homogeneity in a given model of structure formation.

Cosmological N-Body simulations have become an essential tool for studying formation of large scale structure. These simulations are computationally challenging even with the rapid improvement in computing power over time. A number of efficient algorithms have been developed to run large simulations with better dynamic range and resolution. We (Khandai and Bagla, 2008) discuss the performance characteristics of using the modification of the tree code suggested by Barnes (1990) in the context of the TreePM code. The optimization involves identifying groups of particles and using only one tree walk to compute force for all the particles in the group. In this paper, we present the first detailed study of the performance characteristics of this optimization. We show that the modification, if tuned properly can speed up the TreePM code by a significant amount. We also combine this modification with the use of individual time steps and indicate how to combine these two schemes in an optimal fashion. The combined speedup with the two optimizations is at least a factor of ten for realistic models.

We (Bagla and Prasad, 2008) study the interplay of clumping at small scales with the collapse and relaxation of perturbations at larger scales using N-Body simulations. We quantify the effect of collapsed haloes on perturbations at larger scales using two point correlation function, moments of counts in cells and mass function. The purpose of the study is twofold and the primary aim is to quantify the role played by collapsed low mass haloes in the evolution of perturbations at large scales, this is in view of the strong effect seen when the large scale perturbation is highly symmetric. Another reason for this study is to ask whether features or a cutoff in the initial power spectrum can be detected using measures of clustering at scales that are already non-linear. The final aim is to understand the effect of ignoring perturbations at scales smaller than the resolution of N-Body simulations. We find that these effects are ignorable if the scale of non-linearity is larger than the average inter-particle separation in simulations. Features in in the initial power spectrum can be detected easily if the scale of these features is in the linear regime, detecting such features becomes difficult as the relevant scales become non-linear. We find no effect of features in initial power spectra at small scales on the evolved power spectra at large scales.

Preprints:

1. Bagla J. S., Yadav Jaswant and Seshadri T. R., *Fractal Dimension of a Weakly Clustered Distribution and the Scale of Homogeneity*, 0712.2905

2. Bagla J. S. and Prasad Jayanti, *Gravitational collapse in an expanding background and the role of substructure II: Excess power at small scales and its effect of collapse of structures at larger scales*, 0802.2796

3. Bagla J. S. and Khandai Nishikanta, *A Modified TreePM Code*, 0802.3215

Conference/Workshops Attended:

1. *Indo-Brazil Workshop on Cosmology*, India, July, 2007.

2. *Indian Conference on Cosmology and Galaxy Formation*, India, November, 2007.

3. *Field Theoretic Aspects of Gravitation*, India, November, 2007.

4. *International Conference on Gravitation and Cosmology*, India, December, 2007.

5. *Prospects and Problems of Gravitation and Cosmology*, India, January, 2008.

Visits to other Institutes:

1. Indian Institute of Science Education and Research, Mohali, India, October 2007.

2. Raman Research Institute, Bangalore, India, February-March 2008.

Invited Lectures/Seminars:

1. *Simulating formation of large scale structure in the universe*, Colloquium, IISER, Mohali, October 2007.

2. *Fractal dimensions of finite, almost homogeneous distributions*, Colloquium, IISc, Bangalore, March 2008.

Other Activities:

1. I organized the Indian Conference on Cosmology and Galaxy Formation (ICCGF) in November 2007.

2. I am the member-secretary of the INSA-IAU committee for a four year period starting in Jan.1, 2008. I have authored and I manage the web pages for this committee. One of the tasks of this committee is to coordinate activities in the International Year of Astronomy (2009).

3. I am a member of the Scientific Organizing Committee for the forthcoming meeting of the Indian Association for General Relativity and Gravitation.

4. I have started a regular outreach programme at the institute. This programme, funded by INSA, involves inviting batches of about 50 school students for a lecture and an interactive session.

5. I am the principal investigator for the high performance scientific computing XI-plan project. We have started remodeling an area in the institute for housing the cluster facilities that will be set up during the XI-plan. Our plan is to add facilities with a peak performance of more than 3 Tera Flops during 2008-09.

6. As a member of the Rajbhasha committee at the institute, i coordinated lectures in a week long school that we organize every year for students from schools in Allahabad and Jhusi.

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Abhijit Bandyopadhyay

Research Summary:

In a collaboration with S Choubey the implications of extra sterile neutrinos for the Double Chooz experiment is expounded. The so-called "3+2" mass spectrum with 2 sterile neutrinos mixed with the active ones, is still allowed by the global neutrino data including MiniBooNE. We probe its impact on the resultant reactor antineutrino signal at the near and far detector of the Double Chooz experiment. The oscillations driven by the additional mass squared difference due to the sterile states bring an energy independent constant suppression at both the near and far detectors. We study to what extent the measurement of θ_{13} would get affected due to the presence of sterile mixing. We also give the projected sensitivity that Double Chooz will have to constrain the extra mixing angles associated with the sterile states.

In a collaboration with S Choubey, S Goswami, S T Petcov, D P Roy we do a re-analysis to asses the impact of the results of the Borexino experiment and the recent 2.8 KTy KamLAND data on the solar neutrino oscillation parameters. The current Borexino results are found to have no impact on the allowed solar neutrino parameter space. The new KamLAND data causes a significant reduction of the allowed range of Δm^2_{21}, determining it with an unprecedented precision of 8.3precision of Δm^2_{21} is controlled practically by the KamLAND data alone. Inclusion of new KamLAND results also improves the upper bound on $\sin^2\theta_{12}$, but the precision of this parameter continues to be controlled by the solar data. The third mixing angle is constrained to be $\sin^2\theta_{13} < 0.063$ at 3σ from a combined fit to the solar, KamLAND, atmospheric and CHOOZ results. We also address the issue of how much further reduction of allowed range of Δm^2_{21} and $\sin^2\theta_{12}$ is possible with increased statistics from KamLAND. We find that there is a sharp reduction of the 3σ "spread" with enhanced statistics till about 10 KTy after which the spread tends to flatten out reaching to less than 4$\sin^2\theta_{12}$ however, the spread is more than 25exposure and assuming $\theta_{12} < \pi/4$, as dictated by the solar data. We show that with a KamLAND like reactor "SPMIN" experiment at a distance of $\sim$ 60 km, the spread of $\sin^2\theta_{12}$ could be reduced to about 5determined to within 4

In an ongoing collaboration with A Dighe and B Dasgupta we are trying to provide bounds on the couplings of the leptons to $L_e - L_\mu$ type forces, by demanding agreement with existing solar and reactor neutrino da ta. We derive appropriate analytical expressions for the effective masses and mi xings in three regims: Large v limit (V¿1 eV), Non-Hierarchical Small V limit (C ¡ 0.1 eV, m¿0.05 eV) and the Hierarchical Small V limit (V¡0.1 eV, m¡0.01 eV). In particular, we look at the resonances of the various mixing angles. Any sev ere depurture from standard

LMA-MSW results put strong constraints on the coupli ng to the leptonic scalar.

In another ongoing collaboration with S Goswami, K Kar, S Chakraborty we are studng the potential of the supurnova neutrinos on determination of θ_{13} and neutrino mass hierarchy

Presently I have also been working on Simulation of India-based Neutrino Observatory in collaboration with A Raychaudhuri, S Choubey, S Goswami, R Gandhi.

Publications:

1. A. Bandyopadhyay, S. Choubey, S. Goswami and S. T. Petcov, "Solar model parameters and direct measurements of solar neutrino fluxes," Phys. Rev. D **75**, 093007 (2007).

2. A. Bandyopadhyay, A. Dighe and A. S. Joshipura, "Constraints on flavor-dependent long range forces from solar neutrinos and KamLAND," Phys. Rev. D **75**, 093005 (2007) [arXiv:hep-ph/0610263].

Preprints:

1. A. Bandyopadhyay and S. Choubey, "The (3+2) Neutrino Mass Spectrum and Double Chooz," arXiv:0707.2481 [hep-ph].

2. A. Bandyopadhyay, S. Choubey, S. Goswami, S. T. Petcov and D. P. Roy, "Neutrino Oscillation Parameters After High Statistics KamLAND Results," arXiv:0804.4857 [hep-ph].

Conference/Workshops Attended:

1. 10th Workshop in High Energy Physics Phenomenology (WHEPP X), Institute of Mathematical Sciences, Chennai, India, January, 2008.

2. Meeting on India-based Neutrino Observatory, Tata Institute of Fundamental Research, Mumbai, India, January 2008.

3. *NuHoRIzons*, Neutrinos in Physics, Astrophysics and Cosmology, Harish-Chandra Research Institute, Allahabad, India, February, 2008.

4. *Neutrinos and Beams*, Darjeeling, WB, India, May, 2008.

Visits to other Institutes:

1. Theory Group, Saha Institute of Nuclear Physics, Calcutta, India, May 12 - May 24, 2008.

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Priyotosh Bandyopadhyay

Research Summary:

I mainly worked in gaugino non-universality and its effects on cascade Higgs production at the LHC. We studied how the effects going to be different from universality to the non universality for all the Supersymmetric Higgses. We showed how the production cross-section cross over region of charged Higgs and lightest neutral Higgs is shifted for the non-universal case as compared to the universal case. Now we are extending the analysis with proper signal background analysis. We are through for the neutral Higgs case but the charged Higgs part has to be taken care.

Preprints:

1. Priyotosh Bandyopadhyay, Amitava Datta, AseshKrishna Datta, Biswarup Mukhopadhyaya, *Associated Higgs Production in CP-violating supersymmetry: probing the 'open hole' at the Large Hadron Collider,* eprint arXiv:0710.3016v2 [hep-ph] .

Conference/Workshops Attended:

1. *School on QCD at LHC*, HRI, Allahabad, India, November 2007.
2. *From Strings to LHC - II* , Bangalore, India, December 2007.
3. *NeuHorizone* , HRI, Allahabad, India, February 2008.

Visits to other Institutes:

1. IACS, Kolkata, India, December 2008.
2. SINP, Kolkata, India, December 2008.

Invited Lectures/Seminars:

1. *Associated Higgs Production in CP-violating supersymmetry: probing the 'open hole' at the Large Hadron Collider* , Theory group seminar, IACS, Kolkata, December 2007.
2. *Associated Higgs Production in CP-violating supersymmetry: probing the 'open hole' at the Large Hadron Collider*, Theory group seminar, SINP, kolkata, December 2007.

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Nabamita Banerjee

Research Summary:

Publications:

1. Nabamita Banerjee, Dileep Jatkar, Ashoke Sen, *Adding Charges to N=4 Dyons,* JHEP 0707:024,2007.

2. Nabamita Banerjee, Suvankar Dutta, *Phase transition of electrically charged Ricci-flat black holes.,* JHEP 0707:047,2007.

Conference/Workshops Attended:

1. *ISM 07*, India, Oct, 2007,e.g. January, 2008.

2. *FTAG 07*, India, Nov, 2007.

3. *Strings to LHC*, India, Dec, 2007.

4. *2nd Asian School on String Theory*, Japan, Jan, 2007.

Visits to other Institutes:

1. S.N. Bose National Centre for Basic Science, Kolkata, India, Oct, 2007.

2. Institute of Mathematical Science, Chennai, India, Dec, 2007.

Invited Lectures/Seminars:

1. *Phase transition of electrically charged Ricci-flat black holes*, name of the Seminar, S.N. Bose National Centre for Basic Science, Kolkata, India, Oct, 2007.

2. *Adding Charges to N=4 Dyons*, name of the Seminar, Inst. of Mathematical Science, Chennai, India, Dec, 2007.

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Shamik Banerjee

Research Summary:

I am working in string theory under the supervision of Prof.Ashoke Sen. So far my area of research is black-hole microstate counting.

Publications:

1. Shamik Banerjee, Ashoke Sen, Yogesh K. Srivastava, *Partition Functions of Torsion > 1 Dyons in Heterotic String Theory on T**6.* JHEP **0805**, 098, (2008)

2. Shamik Banerjee, Ashoke Sen, Yogesh K. Srivastava, *Generalities of Quarter BPS Dyon Partition Function and Dyons of Torsion Two.* JHEP **0805**, 101, (2008)

3. Shamik Banerjee, Ashoke Sen, *S-duality Action on Discrete T-duality Invariants* JHEP **0804**, 012, (2008)

4. Shamik Banerjee, Ashoke Sen, *Duality orbits, dyon spectrum and gauge theory limit of heterotic string theory on T**6.* JHEP **0803**, 022, (2008)

Preprints:

1. Shamik Banerjee, Ashoke Sen *Interpreting the M2-brane Action.,*
e-Print: arXiv:0805.3930 [hep-th], (2008)

Schools Attended:

1. *2007 BCSPIN Summer School In Particle Physics And Cosmology*

   June 18-26, Beijing , China, Hosted by the Graduate University of Chinese Academy of Sciences.

2. *From Strings to LHC - II* , India, December 2008.

3. *Spring School on Superstring Theory and Related Topics* , ICTP Trieste - Italy, March 2008.

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Subhaditya Bhattacharya

Research Summary:

I have been working in N=1 supersymmetry (SUSY) phenomenology, particularly in the Minimal Supersymmetric Extension of Standard Model (MSSM). My work is mostly related to the collider aspect of SUSY, particularly in context of the upcoming experiment at Large hadron Collider (LHC) in CERN, Switzerland.

In the most simplified framework of SUSY, namely minimal supergravity (mSUGRA), all low scale SUSY breaking parameters are generated from a common scalar mass m_0, common gaugino mass $m_{1/2}$, common trilinear coupling A_0, $\tan\beta$ (ratio of two higgs vacuum expectation values) and the sign of μ (higgsino mass parameter). We study a situation where gaugino and scalar masses at the high scale are non-universal. For gaugino non-universality, we study a theoretical framework of N=1 supergravity embedded in GUT group ($SU(5)$ or $SO(10)$), where the gauge kinetic function belonging to the non-singlet representations (arising from the symmetric product of adjoint representation of underlying GUT group) yields a definite non-universal gaugino mass pattern. For scalar non-universality, we study phenomenological situations where (a) squarks and sleptons are non-universal , (b) third family scalars are non-universal from the first two and a theoretical scenario where (c) non-universality in scalars arising from $SO(10)$ $D-terms$ at the GUT scale. We perform a multichannel analysis with opposite sign and same sign dilepton, trilepton, single lepton channel along with jets, inclusive jets as well as hadronically quiet trilepton channel with large missing energy in a wide region of parameter space for the non-universal scenarios mentioned above. Some distinct features emerge from the study which might be important in distinguishing these non-universal models at the LHC.

In continuation of our earlier works we have been studying the usefulness of hadronically quiet trilepton events in exploring gaugino and scalar non-universality in a model-independent way at the LHC. We also plan to work in $R-$parity violating SUSY and gauge mediated SUSY breaking framework.

Publications:

1. Subhaditya Bhattacharya, AseshKrishna Datta, Biswarup Mukhopadhyaya *Non-universal gaugino masses-A signal based analysis for the Large hadron Collider,* JHEP **0710**,080, (2007)

Preprints:

1. Subhaditya Bhattacharya, AseshKrishna Datta, Biswarup Mukhopadhyaya

Non-universal scalar masses-A signal based analysis for the Large hadron Collider, arXiv:0804.4051 [hep-ph]

Conference/Workshops Attended:

1. *Hadron Collider Physics Summer School 2007*, CERN, Switzerland, June 6-15, 2007.
2. *QCD school*, HRI, November 25-30, 2007.
3. *NuHORIZON*, HRI, Feb 13-15, 2008.

Visits to other Institutes:

1. Indian Association for the Cultivation of Science, Kolkata, December 2007.

Other Activities:

1. Tutor in the Collider Physics course taken by Prof. Biswarup Mukhopadhyaya for the students doing project in High energy physics, Jan-Mar, 2008.
2. Tutor in the Particle Physics course taken by Dr. Srubabati Goswami for the students in 3rd semester, Aug-Jan, 2007.

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Sandhya Choubey

Research Summary:

Neutrinos were the first to give an unambiguous evidence of physics beyond the standard model of particle physics. Neutrino masses and mixings opened a window to look for a more complete theory at a higher scale. While many of the neutrino oscillation parameters are now experimentally known to rather good precision, there are some very crucial missing links in our understanding of the neutrino sector. The agenda for the future in neutrino physics can be broadly categorized into two. (i) Experimentally determine these unknown parameters and phenomenologically reconstruct the neutrino mass matrix. (ii) Look for a consistent theory which explains all experimental data. I have been working on both these aspects with my student and collaborators at HRI.

Among the hitherto unknown parameters of the neutrino mass matrix are the third mixing angle θ_{13}, the CP phase δ_{CP} and the ordering of the neutrino mass eigenstates. All three of these can in principle be probed by shooting neutrino beams over very long distances and looking for flavor conversion. Very intense and pure neutrino beams are a prerequisite in this program, and so are very large and high performance detectors. The challenge is to do this in the best and most cost-effective way. We at HRI, have proposed an experimental set-up, where a pure electron flavor neutrino beam could be sent from CERN to India-based Neutrino Observatory (INO). This so-called Beta-beam has been proposed in the literature and the beam we require could be produced at CERN using highly accelerated ^{8}B and ^{8}Li ions. INO will house a 50 kton magnetized iron detector which will have excellent sensitivity to muon type neutrinos. The CERN to INO distance is close to the so-called "magic baseline", which is most conducive to the measurement of θ_{13} and the mass ordering. In addition, we showed how the neutrino beam energy could be tuned in order to get very large enhancement of the oscillation probability due to matter effects inside earth. Both these features when combined, make this CERN-INO magical Beta-beam set-up exceptionally sensitive to θ_{13} and the mass ordering.

In order to check if the CERN-INO set-up was the best for a Beta-beam we performed a global optimization excercise to find the best radioactive source ions, acceleration, luminosity and source-detector distance. We concluded that while θ_{13} and the mass ordering would be best done at our set-up, to probe CP violation we would optimally use ^{18}Ne and ^{6}He as source ions and place the detector closer at about 700 km from the source. Finally, we proposed to measure all three parameters optimally by using two detectors, one at INO and another at the Gran Sasso laboratory in Italy. We could obtain unprecedented sensitivity in this two-

detector Beta-beam set-up and the projected results are similar to those expected from a high performance Neutrino Factory.

Sterile neutrinos were the subject of much discussion, following the much-awaited MiniBooNE results. Sterile neutrinos would be needed if indeed LSND has seen oscillations with a frequency that demands Δm^2 in the eV^2 range. While the MiniBOONE results did not confirm the oscillation signal seen at the LSND experiment, they could not rule out LSND either. A major reason was that while LSND had observed flavor oscillations in the antineutrino channel, MiniBOONE data is with neutrinos. Another problem with the MiniBOONE data has been the low energy excess in their event spectrum for which there has not been any convincing evidence so-far. This has been a very disturbing aspect of the MiniBOONE results and therefore warrants an independent check One way to probe the presence of sterile neutrinos is to look for their signature in the supernova neutrino signal in next generation detectors. We have studied these signatures in the next generation megaton water Cerenkov detectors and in the upcoming km^3 neutrino telescopes like IceCube. Time dependent modulation of the neutrino signal emerging from the sharp changes in the oscillation probability due to shock effects is shown to be a smoking gun signal for the existence of sterile neutrinos. Effect of turbulence is taken into account and its seen that the shock effects even though diluted, are not completely washed out. Supernova neutrino signal in water detectors could therefore be used to give unambiguous proof for the existence of sterile neutrinos.

We showed that another place to cross-check the LSND signal will be the upcoming reactor antineutrino experiment such as Double Chooz, designed for measuring θ_{13}. The oscillations driven by the additional mass squared difference due to the sterile states bring an energy independent constant suppression at both the near and far detectors at these experiments. We studied to what extent the measurement of θ_{13} would get affected due to the presence of sterile mixing. We also gave the projected sensitivity that Double Chooz will have to constrain the extra mixing angles associated with the sterile states.

We showed that signatures of these extra sterile states could be obtained in TeV energy range atmospheric neutrinos travelling distances of thousands of kilometers. Atmospheric neutrinos in the TeV range would be detected by the upcoming neutrino telescopes. Of course vacuum oscillations of these neutrinos would be very small. However, we showed that resonant matter effects inside the Earth could enhance these very tiny oscillations into near-maximal transitions, which should be hard to miss. Not only would neutrino telescopes tell the presence of sterile neutrinos, it should also be possible for them to distinguish between the different possible mass and mixing scenarios with additional sterile states.

Finally, we expounded the impact of extra sterile species on the ultra high energy neutrino fluxes in neutrino telescopes. We used three types of well-known flux ratios and compared the values of these flux ratios in presence of sterile neutrinos, with those predicted by deviation from the tribimaximal mixing scheme. We showed that it is easy to confuse between the signature of sterile neutrinos with that of the deviation from tribimaximal mixing. We also showed that if the measured flux ratios acquire a value well outside the range predicted by the standard scenario with three active neutrinos only, it might be possible to tell the presence of extra sterile neutrinos by observing ultra high energy neutrinos in future neutrino telescopes.

Among all neutrino mixing parameters, the atmospheric neutrino mixing angle θ_{23} introduces the strongest variation on the flux ratios of ultra high energy neutrinos. We investigated the potential of these flux ratio measurements at neutrino telescopes to constrain θ_{23}. We concluded that in favorable but not unrealistic situations we can indeed expect useful and complementary limits on θ_{23} which are comparable to the ones from dedicated oscillation experiments.

While we are planning new experiments to measure the completely unknown parameters of the neutrino mass matrix, the ones which we already known to some extent also have to be determined more precisely. In particular, the KamLAND reactor antineutrino experiment in Japan, which was a key player in establishing neutrino oscillations by showing unambiguously oscillations of terrestrially produced beams, released a very high statistics data in early 2008. Another new result came from the Borexino solar neutrino experiment in Italy. We did a reanalysis to asses the impact of the results of the Borexino experiment and the recent 2.8 KTy KamLAND data on the solar neutrino oscillation parameters. The current Borexino results are found to have no impact on the allowed solar neutrino parameter space. The new KamLAND data causes a significant reduction of the allowed range of Δm^2_{21}, determining it with an unprecedented precision of 8.3% at 3σ, however θ_{12} is not constrained much by KamLAND. We show that with a KamLAND like reactor "SPMIN" experiment at a distance of ~ 60 km, the spread of $\sin^2\theta_{12}$ could be reduced to about 5% at 3σ level while Δm^2_{21} could be determined to within 4%, with just 3 KTy exposure.

Our current understanding of neutrino mixings prod us to believe that the mixing matrix in the lepton sector could be of the tribimaximal (TBM) mixing form, first proposed by Harrison, Perkins, and Scott. The challenge for model builders lies in explaining all features of lepton mixing matrix together with the mass pattern of the neutrinos. It has been shown that tribimaximal mixing can be obtained by some particular breaking pattern of the A_4 symmetry, wherein the extra A_4 triplet Higgs scalars pick up certain fixed vacuum expectation value (VEV) alignments. We have performed a detailed analysis of the different possible neutrino

mass matrices within the framework of the A_4 model. We take into account all possible singlet and triplet Higgs scalars which leave the Lagrangian invariant under A_4. We break A_4 spontaneously, allowing the Higgs to take any VEV in general. We showed that the neutrino mixing matrix deviates from tribimaximal, both due to the presence of the extra Higgs singlets, as well as from the deviation of the triplet Higgs VEV from its desired alignment, taken previously. We solve the eigenvalue problem for a variety of these illustrative cases and identify the ones where one obtains exact tribimaximal mixing. All such cases require fine-tuning. We showed which neutrino mass matrices would be strongly disfavored by the current neutrino data. Finally, we studied in detail the phenomenology of the remaining viable mass matrices and established the deviation of the neutrino mixing from tribimaximal, both analytically as well as numerically.

Publications:

1. Abhijit Bandyopadhyay, Sandhya Choubey, Srubabati Goswami, S. T. Petcov, D. P. Roy, *Neutrino Oscillation Parameters After High Statistics KamLAND*, arXiv:0804.4857, under review in Phys. Lett. B.

2. Sanjib K. Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, *Exceptional Sensitivity to Neutrino Parameters with a Two Baseline Beta-Beam Set-up*, arXiv:0804.3007, under review in Nucl. Phys. B.

3. Sandhya Choubey, Viviana Niro, Werner Rodejohann, *On Probing theta(23) in Neutrino Telescopes*, arXiv:0803.0423, to appear in Phys. Rev. D (2008).

4. Sanjib K. Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, Walter Winter, *Optimizing the greenfield Beta-beam*, arXiv:0802.3621, under review in JHEP.

5. Biswajoy Brahmachari, Sandhya Choubey, Manimala Mitra, *The A(4) flavor symmetry and neutrino phenomenology*, Phys. Rev. D **77**, 073008 (2008).

6. Sanjib K. Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, *Unraveling neutrino parameters with a magical beta-beam experiment at INO*, Nucl. Phys. B **798**, 124 (2008).

7. Sandhya Choubey, *Signature of sterile species in atmospheric neutrino data at neutrino telescopes*, JHEP **0712**, 014 (2007).

8. Abhijit Bandyopadhyay, Sandhya Choubey, *The (3+2) neutrino mass spectrum and double chooz*, under review in Phys. Lett. B.

9. Ram Lal Awasthi, Sandhya Choubey, *Confusing sterile neutrinos with deviation from tribimaximal mixing at neutrino telescopes*, Phys. Rev. D **76**, 113002 (2007).

10. Sanjib Kumar Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, *Physics with Beta-Beam*, AIP Conf. Proc. **981**, 84 (2008).

11. Sanjib Kumar Agarwalla, Sandhya Choubey, Amitava Raychaudhuri, *Magic baseline beta beam*, AIP Conf. Proc. **939**, 265 (2007).

12. Sandhya Choubey, N.P. Harries, G.G. Ross, *Turbulent Supernova Shock Waves and the Sterile Neutrino Signature in Megaton Water Detectors*, Phys. Rev. D **76**, 073013 (2007).

Preprints:

1. Sandhya Choubey and other members of ISS physics working group, *International scoping study of a future Neutrino Factory and Super-beam facility*. arXiv:0710.4947

Conference/Workshops Attended:

1. *Indo-Japan Joint Meeting, SINP, Kolkata*, June 2007.

2. *9th International Workshop on Neutrino Factories, Superbeams and Betabeams, NuFact07*, Japan, August 2007.

3. *III International Pontecorvo Neutrino Physics School*, Ukraine, September 2007.

4. *Xth Workshop on High Energy Physics Phenomenology (WHEPP-X)*, Chennai, January 2008.

5. *NuHoRIzons, Neutrinos in Physics, Astrophysics and Cosmology*, Allahabad, February 2008.

Visits to other Institutes:

1. University of Southampton, Southampton, United Kingdom, April 5-11, 2008.

2. Saha Institute of Nuclear Physics, June, 2007.

Invited Lectures/Seminars:

1. *Physics with Betabeams*, Invited plenary talk at "IX International Workshop on Neutrino Factories and Superbeams", NuFact07, Okayama University, Okayama, Japan, August 6-11, 2007.

2. *Neutrino Oscillation Parameters: Results and Prospects*, Lecture series at "III International Pontecorvo Neutrino Physics School", Dubna House, Alushta, Ukraine, September 16-26, 2007.

3. *Probing the Neutrino Mass Matrix in Long Baseline Experiments* Talk at "Indo-Japan Joint Meeting", SINP, Kolkata, June 6-7, 2007.

4. *Summary of Neutrino Working Group*, Summary talk of the Neutrino Working Group at "Xth Workshop on High Energy Physics Phenomenology (WHEPP-X)", IMSc, Chennai, January 2-13, 2008.

5. *Optimizing the Greenfield BetaBeam*, Talk at "NuHoRIzons, Neutrinos in Physics, Astrophysics and Cosmology", HRI, Allahabad, February 13-15, 2008.

6. *Long Baseline Experiments and INO*, Talk at "Joint UKNF, INO, UKIERI meeting 2008", University of Warwick, United Kingdom, April 3-4, 2008.

7. *Neutrino Phenomenology: An Outlook*, Seminar at University of Southampton, Southampton, United Kingdom, April 10, 2008.

8. *Neutrino Beams and INO*, Invited talk at "Neutrinos and Beams", Darjeeling, India, May 5-7, 2008.

Other Activities:

1. Organizing schools/conferences:

   (a) Co-ordinator of the Neutrino Working Group at " Xth Workshop on High Energy Physics Phenomenology (WHEPP-X)", held at IMSc, Chennai, January 2-13, 2008.

   (b) Member of the organizing committee of "NuHoRIzons, Neutrinos in Physics, Astrophysics and Cosmology", held at HRI, Allahabad, February 13-15, 2008.

   (c) Member of the National Organizing Committee, The 18th DAE-BRNS High Energy Physics Symposium, BHU, Varanasi, December 2008.

   (d) Convenor of the Neutrino Oscillation Physics (WG1) of the International Workshop on Neutrino Factories, Superbeams and Betabeams, NuFact08, Valencia, Spain, June, 2008.

2. Teaching at HRI: Gave a special course on 'Statistical Modeling of Data and Error Analysis in HEP', March-May, 2006.

3. Mentoring PhD Students:

   (a) Manimala Mitra

4. Mentoring Project Students:

   (a) Ram Lal Awasthi (now at HRI, Allahabad)
   (b) Sampurna Anand (Kirorimal College, Delhi)

5. Reviewing Papers: Refereed papers for

   (a) Physical Review D
   (b) Journal of High Energy Physics
   (c) Physica Scripta.

6. Talks at HRI:

   (a) *Radiative Neutrino Mass, Dark Matter and Leptogenesis*, pheno-lunch on January 22, 2008.

7. Committees Served:

   (a) Office and Furniture Committee (Convenor)
   (b) Pantry (Member)
   (c) Security (Member)
   (d) Women's Grievance Cell (Member)
   (e) HRIRA (Chair-person)

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Tapas Kumar Das

Research Summary:

I continue to work on various aspects of black hole astrophysics.

Publications:

1. Bozena Czerny (CAMK), Monica Moscibrodzka (UIUC), Daniel Proga (UNLV), Tapas Das (HRI), & Aneta Siemiginowska (Harvard), 2007, *Low angular momentum accretion flow model of Sgr A* activity*, `arXiv:0710.2426`.

Visits to other Institutes:

1. N. Copernicus Astronomical Institute, Warsaw, Poland (June - July, 2007).
2. Marian Smoluchowski Institute of Physics. Jagiellonian University, Cracow, Poland (June 2007).
3. Instytut Fizyki, Universytet Szczecinski, Szczecin, Poland (July 2007).
4. Institute of the Academy of Sciences of the Czech Republic, Prague, Czech Republic (July - August 2007).
5. Institute of Theoretical Physics, Charles University, Prague, Czech Republic (August 2007).
6. Indian Association for the Cultivation of Science (2007).
7. Presidency College, Calcutta (2007).
8. Relativity & Cosmology Research Centre, Jadavpur University, Calcutta (2008).
9. Theoretical Institute of Advance Research in Astrophysics (Academia Sinica), Taiwan (March - April 2008).

Invited Lectures/Seminars:

1. Seminar at Marian Smoluchowski Institute of Physics. Jagiellonian University, Cracow, Poland, on *Black Hole Analogue*, June, 2007.
2. Seminar at N. Copernicus Astronomical Institute, Warsaw, Poland, on *Analogue Gravity Phenomena*, June, 2007.

3. Seminar at Instytut Fizyki, Universytet Szczecinski, Szczecin, Poland, on *Analogue Gravity Models*, July, 2007.

4. Seminar at Astronomical Institute of the Academy of Sciences of the Czech Republic (Group of Relativistic Astrophysics) in Prague, on *Analogue Gravity Effects in Black Hole Astrophysics*, July, 2007.

5. Seminar at Institute of Theoretical Physics, Charles University, Prague, Czech Republic, on 'General relativistic axisymmetric black hole accretion', August, 2007.

6. Seminar at Indian Association for the Cultivation of Science, India, on 'Black Holes in a Bathtub', August, 2007.

7. Seminar at Presidency College, Calcutta, on 'Table-top Black Holes', August, 2007.

8. Seminar at Relativity & Cosmology Research Centre, Jadavpur University, Calcutta, on 'Analogue Gravity in Astrophysics', February, 2008.

Other Activities:

1. Mentoring project students:

   (a) Supervised (September - November 2007) Ms. Jasleen Lugani, M.Sc. final year student of the Physics Department, Punjab University, Chandigarh.

   (b) Supervised (October - November 2007) Mr. Devagnik Dasgupta, M.Sc. student from Jadavpur University.

   (c) Supervised (October - November 2007) Ms. Ipsita Chakraborty, M.Sc. from Presidency college, Calcutta.

   (d) Supervised (October - November 2007) Ms. Urmi Shah, M.Sc. student from MS University, Baroda.

2. Teaching & Lecture Course:

   (a) Taught 'Classical Mechanics' at HRI graduate school (Aug. - Dec.) in 2007.

3. Journal Club Review Talk:

   (a) *Is Violation of Newton's Second Law Possible?*, April 2007.

4. HRI Internal Duty:

   (a) Served as a member of the Sports and Entertainment Committee,Medical Committee and Horticulture Committee.

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AseshKrishna Datta

Research Summary:

During 2007 - 2008, I have been working mainly on the following areas:

1. Signal based studies at the Large Hadron Collider (LHC) of different new physics scenarios like Supersymmetry (SUSY), different extra-dimensional scenarios, scenarios of alternate electroweak symmetry breaking etc.
2. Distinctive features of different new physics scenarios which can lead to an otherwise similar signatures at the LHC; spin-information of the new excitations
3. The Inverse Problem of going from LHC-data to the underlying theory
4. Phenomenology of CP-violating SUSY scenarios and SUSY scenarios with high-scale non-universalities in the SUSY spectrum

Publications:

1. S. Bhattacharya, Asesh Datta and B. Mukhopadhyaya, *Non-universal scalar masses: a signal-based analysis for the Large Hadron Collider arXiv:0804.4051 [hep-ph]*.
2. P. Bandyopadhyay, A. Datta, Asesh Datta and B. Mukhopadhyaya, *Associated Higgs Production in CP-violating supersymmetry: probing the 'open hole' at the Large Hadron Collider arXiv:0710.3016 [hep-ph]*.
3. S. Bhattacharya, Asesh Datta and B. Mukhopadhyaya, *Non-universal gaugino masses: a signal-based analysis for the Large Hadron Collider arXiv:0708.2427 [hep-ph]*, JHEP 10 (2007) 080.
4. Asesh Datta, P. Dey, S. K. Gupta, B. Mukhopadhyaya and A. Nyffeler, *Distinguishing the Littlest Higgs model with T-parity from supersymmetry at the LHC using trileptons arXiv:0708.1912 [hep-ph]*, Phys.Lett.B659:308-315,2008.

Preprints:

1. P. Bandyopadhyay, Asesh Datta and B. Mukhopadhyaya, *Hints of gaugino mass non-universality in Higgs production under SUSY cascades at the LHC*
2. P. Bandyopadhyay, Asesh Datta and B. Mukhopadhyaya, *A detailed analysis of the role of gaugino mass non-universality in Higgs production at the LHC*

Visits to other Institutes:

1. Invited to attend "SUSY08" to be held at Seoul, Korea in June, 2008. Could not attend due to a serious mistake made by the Regional Passport Office, Lucknow in my re-issued passport.

2. Invited for a summer (2008) visit to CERN, Geneva, Switzerland. Could not attend due to a serious mistake made by the Regional Passport Office, Lucknow in my re-issued passport.

3. Invited to attend "Physics of the Large Hadron Collider" being held at KITP, Santa Barbara, USA during February–June, 2008. Could not attend due to a serious mistake made by the Regional Passport Office, Lucknow in my re-issued passport.

4. Participated in WHEPP-X held at the Institute of Mathematical Sciences, Chennai in January, 2008.

5. Participated in the topical conference "From Strings to LHC-II" organised by Tata Institute of Fundamental Research and held in Bangalore, India, in December, 2007.

6. Participated in the The 15th International Conference on Supersymmetry and the Unification of Fundamental Interactions (SUSY07) held at Karlsruhe, Germany during July-August, 2007. Visited Universitat Karlsruhe during July-August, 2007.

7. Invited to the Les Houches Workshop "Physics at TeV Colliders" held at Les Houches, France in June, 2007. Could not attend the same due to personal reasons.

Invited Lectures/Seminars/Articles:

1. Invited as a speaker in the parallel session of "SUSY08" to be held at Seoul, Korea in June, 2008. Could not attend the same for reasons mentioned earlier.

2. Invited as a plenary speaker in HEPCOS-08 organised by CTP, Jamia-Milia Islamia, New Delhi in March, 2008. Could not attend since I was busy with my passport related problems mentioned earlier.

3. Gave an invited talk on "Deciphering New Physics at LHC" at the topical conference "From Strings to LHC-II" organised by Tata Institute of Fundamental Research and held at Bangalore, India, during December, 2007.

4. Invited to write a contributory article for the special volume on *Physics at the Large Hadron Collider*, to be published in commemoration of the Platinum Jubilee of the Indian National Science Academy (INSA).

Other Activities:

1. Course Given: A semester-long course on Classical Electrodynamics in the fall semester, 2007.

2. Mentoring project students:

   (a) During the period I offered two reading courses (project) on 'Searches for Standard Model Higgs bosons and Higgs bosons of the Minimal Supersymmetric Standard Model (MSSM) at present and future colliders' to two of our young graduate students who later joined the phenomenology group for their Ph.D. degree.

   (b) A visiting consultant/student worked with me for five months (January to May, 2008) on building up and streamlining the computing facilities used by the collider physics group here at HRI.

3. Reviewing papers:

   Served as a referee for the following journal(s):

   (a) One paper submitted to the Indian Journal of Physics

4. HRI Internal Duty:

   (a) Serving as a member of the Computer Committee.

   (b) Serving as the convener of the Sports and Entertainment Committee.

   (c) Serving as the Technical Coordinator of the newly formed Regional Centre for Accelerator-based Particle Physics (RECAPP) at HRI (see below).

5. Organizing Workshops/Conferences/Schools etc.:

   (a) Remotely involved in organizational aspects of the Higgs Hunters' Meeting held in Visva-Bharati, Santiniketan (March, 2008) under the auspices of RECAPP.

(b) Served as one of the conveners for the 10th Workshop on High Energy Physics Phenomenology (WHEPP-X, with international participation) held at Chennai, India during January, 2008 (mentioned also in last year's report when the offer came and I accepted the same).

(c) Organized at HRI a pedagogical School on QCD at LHC (with international participation) in November, 2007 along with my colleagues from HRI (mentioned also in last year's report when the plan for the school was finalized).

6. Project RECAPP:

This is a group-effort in which I have been taking immense interest and devoting crucial amount of time (as its Technical Coordinator) along with my colleagues towards bringing up an advanced computing facility for research in physics connected to present high energy collider like the Tevatron, an upcoming collider like the Large Hadron Collider (LHC) and a future Linear Collider (LC). RECAPP envisages providing a common platform and state-of-the art computing facility related to HEP to senior and young physicists working in this broad area and who hail from the region. The center is expected to strengthen collaborations in the region. We are already having enhanced collaborative activities among the members of RECAPP at different levels.

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Justin R. David

Research Summary:

My research during 2007-2008 centered on two distinct aspects of string theory: i) The gauge/gravity correspondence, ii) Understanding the spectrum of dyonic states in a class $\mathcal{N} = 2$ string theories.

On the topic of gauge/string duality in collaboration with R. Gopakumar and and the group at Weizmann Institute we continued to investigate properties of world sheet conformal field theories which are conjectured to be dual to free large N gauge theories. With R. Gopakumar and A. Mukhopadhyay we constructed worldsheet correlators corresponding to a class of chiral primaries in free, planar $\mathcal{N} = 4$ Yang-Mills in the large J limit. The world sheet correlator exhibits the appropriate crossing symmetry. In collaboration with B. Sahoo and A. Sen we argued that as a consequence of AdS/CFT correspondence, the entropy of the BTZ black hole in three dimensional supergravity with $(0, 4)$ supersymmetry is not renormalized by any higher derivative corrections. In collaboration with B. Sahoo we studied the supersymmetry properties of giant magnons in the near horizon $AdS_3 \times S^3$ geometry of the D1-D5 system and derived their dispersion relation.

We proposed a partition function involving the product of three Siegel modular forms which reproduces the degeneracy of dyonic black holes in a particular $\mathcal{N} = 2$ string compactification to the first sub-leading order in charges. The proposal is invariant under all the duality symmetries of the theory. At present we are involved in further tests of this proposal.

Publications:

1. Ofer Aharony, Justin R. David, Rajesh Gopakumar, Zohar Komargodski, Shlomo S. Razamat, *Comments on worldsheet theories dual to free large N gauge theories* , Phys.Rev. **D75**, 106006, (2007)

2. Justin R. David, Bindusar Sahoo, Ashoke Sen *AdS_3, Black holes and higher derivative corrections,* JHEP **0707** , 058, (2007)

3. Justin R. David , *On the dyon partition function in $\mathcal{N} = 2$ theories.,* JHEP **0802** , 025, (2008)

Preprints:

1. Justin R. David and Bindusar Sahoo, *Giant magnons in the D1-D5 system,* arXiv:0804.3267.

2. Justin R. David, Rajesh Gopakumar and Ayan Mukhopadhyay, *Worldsheet properties of extremal correlators in AdS/CFT,* (in preparation).

Conference/Workshops Attended:

1. *IPM String School and Workshop*, Iran, April, 2007.
2. *Fourth Regional Meeting in String Theory*, Greece, June, 2007.
3. *XXXVIIth Paris Summer Institute on Black Holes, Black Rings and Modular Forms,* Paris, August, 2007.
4. *National Strings Meeting*, Allahabad, October, 2007.

Visits to other Institutes:

1. Indian Institute of Science, Bangalore, May, 2007.
2. LPTHE, Jussieu, Paris, June-August, 2007.

Invited Lectures/Seminars:

1. *On the dyon partition function in $\mathcal{N} = 4$ string theories,* IPM String School and Workshop, IPM, Tehran, Iran, April, 2007.
2. *Black Holes in String theory,* Physics Colloquium, Indian Institute of Science, Bangalore, May, 2007.
3. *Dyonic black hole in N=4 string compactifications,* Fourth Regional Meeting in String theory, Patras, Greece, June, 2007.
4. *On the partition function of dyons in the FHSV model,* XXXVIIth Paris Summer Institute on Black Holes, Black Rings and Modular Forms, Ecole Normale Supérieure, Paris, August, 2007.
5. *On the partition function of dyons in $\mathcal{N} = 2$ string theories,* National Strings Meeting, HRI, October, 2007.

Other Activities:

1. Instructor: Mathematical Methods-I, August-December, 2007.

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Paramita Dey

Research Summary:

In a collaboration with A. Dutta, S.K. Gupta, A. Nyffeler and B. Mukhopadhyaya, we explored some aspects of the collider phenomenology of the Littlest Higgs Model with T-parity (LHT) at the LHC. This model predicts the existence of heavier T-odd partners of all of the Standard Model (SM) fermions and bosons (which are considered to be T-even), which can have masses in the range of a few hundreds of GeV to a few TeV, and may thus be produced at the LHC (operating around the center of momentum energy $\sqrt{s} = 14$ TeV). We analyzed hadronically quiet trilepton signatures in this model, and in R-parity conserving supersymmetry at the LHC in order to distinguish between them, even if the corresponding mass spectra, as measured at LHC, are identical. We found that there are regions of the parameter space where such signals can reveal the presence of these new physics models above the Standard Model background, and clearly distinguish them from each other.

In a collaboration with A. Kundu and B. Mukhopadhyaya, we considered an extension of the scalar sector of the Standard Model with a single complex Higgs triplet X. Such extensions are the most economic, model-independent way of generating neutrino masses through triplet interactions. We showed that a term like $a_0 \Phi\Phi X^\dagger$ must be included in the most general potential of such a scenario, in order to avoid a massless neutral physical scalar. We also demonstrated that a_0 must be real, thus ruling out any additional source of CP-violation. We examined the implications of this term in the mass matrices of the singly-and doubly-charged scalar, neutral scalar and pseudoscalar fields. We found that, for small values of a_0/v_2, where v_2 is the triplet VEV, the spectrum allows the decay of heavier scalars into lighter ones via gauge interactions. For large a_0/v_2, the doubly-charged, singly-charged and neutral pseudoscalar bosons become practically degenerate, while the even-parity neutral scalars remain considerably lighter, thus emphasizing the possibility of decay of the singly-charged or neutral pseudoscalar states into the neutral scalars. We also studied the couplings of the various physical states in this scenario. For small values of $|a_0|/v_2$, we found the lightest neutral scalar field to be triplet-dominated, and thus having extremely suppressed interactions with fermion as well as gauge boson pairs.

In an ongoing collaboration with A. Kundu, S. Nandi and B. Mukhopadhyay we are trying to explore the possibility of generation of neutrino Majorana mass at the loop level, starting from the most economic R-parity violating supersymmetric scenario. We find that if we have *only* three nonzero lepton number violating trilinear λ'-type couplings, namely λ'_{121}, λ'_{223} and λ'_{323}, it is in general possible to

have small neutrino Majorana masses generated at the two-loop level. The resulting loop suppression even allows all these λ''s to be ~ 1. By constructing the neutrino mass matrix, we are trying to see whether this scenario can explain the experimentally measured neutrino masses and mixing angles.

In another ongoing collaboration with S.K. Gupta and B. Mukhopadhyay we are trying to explore the Littlest Higgs Model with T-parity (LHT) in the context of direct detection of dark matter. The model predicts the existence of heavier T-odd partners of all of the Standard Model (SM) fermions and bosons (which are considered to be T-even). The lightest T-odd particle being stable as a consequence of T-parity is a potential dark matter candidate. We are mainly interested in exploring a particular region of the allowed parameter space of LHT, in which the T-odd neutrinos are the lightest T-odd particles (instead of the T-odd photons).

Publications:

1. P. Dey, A. Abada, G. Moreau, *Neutrinos in flat extra dimension: towards a realistic scenario,* JHEP **09**, 006, (2007)

2. P.Dey, A. Dutta, S. K. Gupta, A. Nyffeler, B. Mukhopadhyaya, *Distinguishing the Littlest Higgs model with T-parity from Supersymmetry at the LHC using trileptons,* Phys. Lett. **B659**, 308, (2008)

Preprints:

1. P.Dey, A. Kundu, B. Mukhopadhyaya, *Some consequences of a Higgs triplet,* arXiv:0802.2510

2. P.Dey, A. Kundu, S. Nandi, B. Mukhopadhyaya, *Neutrino mass from R-parity violating supersymmetry,* (in preparation)

3. P.Dey, S.K. Gupta, B. Mukhopadhyaya, *The T-odd neutrino of Littlest Higgs Model with T-parity as a dark-matter,* (in preparation)

Conference/Workshops Attended:

1. School on QCD at LHC, Regional Center for Accelerator-based Particle Physics (ReCAPP), Harish-Chandra Research Institute, Allahabad, India, November, 2007.

2. 10th Workshop in High Energy Physics Phenomenology (WHEPP X), Institute of Mathematical Sciences, Chennai, India, January, 2008.

3. Higgs Hunters' Meeting, Visva-Bharati, Shantiniketan, India, February, 2008.

4. *NuHoRIzons*, Neutrinos in Physics, Astrophysics and Cosmology, Harish-Chandra Research Institute, Allahabad, India, February, 2008.

Visits to other Institutes:

1. Department of Physics, Calcutta University, Calcutta, India, May 12-May 31, 2007.

2. Center for High Energy Physics, Indian Institute of Science, Bangalore, India, June 21-July 5, 2007.

3. Department of Physics, Calcutta University, Calcutta, India, Sep 15-Sep 22, 2007.

4. Department of Physics, Calcutta University, Calcutta, India, Dec 16-Jan 1, 2008.

5. Department of Physics, Calcutta University, Calcutta, India, May 19-Jun 3, 2008.

Invited Lectures/Seminars:

1. *Neutrinos in Flat Extra Dimension: Towards a Realistic Scenario*, Center for High Energy Physics, Indian Institute of Science, Bangalore, India, July, 2007.

2. *Some Consequences of a Higgs Triplet*, Higgs Hunters' Meeting, Visva-Bharati, Shantiniketan, India, February, 2008.

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Suvankar Dutta

Research Summary:

Publications:

1. Suvankar Dutta, Nabamita Banerjee *Phase transition of electrically charged Ricci-flat black holes.,* HEP 0707:047,2007.

2. Suvankar Dutta, Rajesh Gopakumar, *Free fermions and thermal AdS/CFT.,* JHEP 0803:011,2008.

Conference/Workshops Attended:

1. *ISM 07*, India, Oct, 2007,e.g. January, 2008.

2. *2nd Asian School on String Theory*, Japan, Jan, 2007.

Visits to other Institutes:

1. CERN, Geneva, Switzerland, Nov, 2007.

2. AEI, Potsdam, Germany,Nov, 2007 .

3. LPTENS, Paris, France,Nov, 2007 .

4. ICTP, Trieste, Italy,Nov, 2007 .

Invited Lectures/Seminars:

1. *Free Fermions and Thermal AdS/CFT*, name of the Seminar, ISM 07, Allahabad, Oct, 2007.

2. *Free Fermions and Thermal AdS/CFT*, name of the Seminar, AEI, Potsdam; LPTENS, Paris; CERN, Geneva; ICTP, Italy, Nov, 2007.

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Raj Gandhi

Research Summary:

The neutrino mass hierarchy is an important unresolved question in particle physics. Its importance is due to the fact that it provides a window to building unified theories beyond the Standard Model. It is intimately linked to CP violation at higher scales, and to the baryon asymmetry of the universe via mechanisms of leptogenesis. With my collaborators (P. Ghoshal, S Goswami and S. Uma Sankar) we have explored ways in which the hierarchy may be determined using atmospheric neutrinos in detectors which are currently planned or proposed worldwide, including the Indian Neutrino Obsevatory (INO). In particular, our recent work is focussed on determining the hierarchy for the challenging situation of zero or very small θ_{13}.

I was part of Physics Working Group of the international scoping study of a future Neutrino Factory and super-beam facility (the ISS). The ISS was carried out by the international community to examine the physics case for an extensive experimental programme to understand the properties of the neutrino. It studied the role of high-precision measurements of neutrino oscillations. The performance of second generation super-beam experiments, beta-beam facilities, and the Neutrino Factory were evaluated and a quantitative comparison of the discovery potential of the three classes of facility was presented. The nearly one-and a half year long study culminated in a detailed report submitted in October 2007.

At present, in additon to the above, I am interested in studying and investigating the relevance of the Berry phase in neutrino oscillations, and the important issue of leptogenesis.

Publications:

1. Raj Gandhi, Pomita Ghoshal, Srubabati Goswami (Harish-Chandra Res. Inst.) , Poonam Mehta (Weizmann Inst.) , S.Uma Sankar (Indian Inst. Tech., Mumbai) , Shashank Shalgar (Harish-Chandra Res. Inst.), *Mass Hierarchy Determination via future Atmospheric Neutrino Detectors.,* Phys.Rev.D **76**, 073012, (2007)

Preprints:

1. Raj Gandhi, Pomita Ghoshal, Srubabati Goswami, S.Uma Sankar., *Mass hierarchy determination using atmospheric neutrinos for small theta(13).,* arXiv:0805.3474 [hep-ph], May 2008. 5pp.

2. ISS Physics Working Group , *Physics at a future Neutrino Factory and super-beam facility.* arXiv:0805.3474 [hep-ph],Oct 2007. 370pp.

Conference/Workshops Attended:

1. *Neutrinos: Looking Forward*, USA, May, 2007.

Visits to other Institutes:

1. Aspen Center for Physics, Aspen, CO, USA, May, 2007.
2. SLAC Theory Group, Stanford, USA, June, 2008.

Invited Lectures/Seminars:

1. *Mass Hierarchy Determination using Atmospheric Neutrinos*, Invited Talk at the Aspen Meeting on Neutrinos: Looking Forward, Aspen, USA, May, 2007.
2. *Mass Hierarchy Determination using Atmospheric Neutrinos*, Theory Seminar, SLAC Theory Group, Stanford University, June 2008.

Other Activities:

1. Pomita Ghoshal, my student, will defend her thesis this July. She is at present doing her postdoc at TIFR.
2. I have guided 2 students, Saba Khan from IIT Delhi and Aarti Raghuraman from IIT Chennai for student projects in the summer of 2007.
3. I continue to play an active role in INO activities and am a member of the Program Management Committee.
4. I have taught a 6 week special topics course on Particle Physics in Spring 2007.
5. I am a member of the UK-India Education and Research Initiative (UKIERI), a three year collaborative project between the 2 countries to investigate neutrino physics.

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Debashis Ghoshal

Research Summary:

The idea of generalised complex and Kähler structure have been proposed by Hitchin. Examples of these structures arise in the context of string theory. We extend the notion to define generalised hyper-Kähler structure and provide natural examples in string theory.

Aspects of logarithmic conformal field theories (LCFT) are being studied in collaboration with Turbasu Biswas. In particular, behaviour of LCFT under a relevant perturbation as well as the one-loop characters of these theories are being investigated.

On lien to the School of Physical Sciences, Jawaharlal Nehru University, New Delhi since July 2007.

Publications:

1. B. Ezhuthachan and D. Ghoshal, *Generalised hyperKähler manifolds in string theory,* JHEP **0704**:083, (2007)

Conference/Workshops Attended:

1. *Logarithmic conformal field theories & statistical mechanics*, Russia, June 2007.

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Manoj Gopalakrishnan

Research Summary:

A general stochastic theory of the kinetics of ligand binding to cell surface receptors was presented for a spherical cell. The time evolution of ligand density as well as ligand-bound receptor fraction was explicitly calculated and characterized for different temporal regimes. Interestingly, deviations were found from the classical Berg-Purcell theory and their implications are currently being studied. The probability distribution of the number of repeated bindings is also under investigation (in collaboration with Shivam Ghosh and Kimberly Forsten-Williams).

In olfactory signal transduction, a functional Fokker-Planck equation was derived to understand signal integration along the "one-dimensional" olfactory cilium. Preliminary results show that, in the presence of Ca-induced negative feedback, the initial linear response is weakened by feedback, thus giving rise to the experimentally observed non-linear response. This non-linearity approximates a threshold in agreement with observations, and the threshold is deemed to be important in suppressing thermal noise (in collaboration with Peter Borowski and Martin Zapotocky).

A model of depolymerization of microtubules by kinesin-13 proteins (MCAK) has been formulated. It was shown that the presence of MCAK could lead to a non-exponential distribution of microtubule lengths in steady state, above a critical concentration. Implications of these findings in the context of the formation of the metaphase spindle is currently under study (in collaboration with Bindu Govindan and Debashish Chowdhury).

Other problems of interest that are currently in various stages of progress are (i) characterizing motor protein motion and forces in the visco-elastic cytoplasm (with Roop Mallik) (ii) a coarse-grained model for formation ofn Cajal bodies in the nucleoplasm (with Martin Zapotocky and David Stanek) (iii) a stochastic model of chemosensory detection in E. Coli bacterium (with Mahesh Tirumkudulu) (iv) a stochastic model of search and capture of chromosomes by microtubules in space (with Bindu Govindan).

Publications:

1. Manoj Gopalakrishnan, Peter Borowski, Frank J/"ulicher and Martin Zapotocky*Response and fluctuations of a two-state signaling module with feedback,* Phys. Rev. E **76**, 021904, (2007)

2. Shivam Ghosh, Manoj Gopalakrishnan and Kimberly Forsten-Williams*Self-*

consistent theory of reversible ligand binding to a spherical cell, Phys. Biol. **4**, 344, (2007)

3. Bindu S. Govindan, Manoj Gopalakrishnan and Debashish Chowdhury, *Length control of microtubules by depolymerizing motor proteins,* Europhys. Lett. (in press, 2008)

Preprints:

1. Bindu S. Govindan, Manoj Gopalakrishnan and Debashish Chowdhury, *MCAK selectively targets long microtubules for depolymerization,* ICTP preprint IC/2007/060 (2007).

2. Manoj Gopalakrishnan and Bindu S. Govindan, *Stochastic model of microtubules searching for fixed targets in space* (2008,in preparation).

Visits to other Institutes:

1. Department of Physics, IIT Bombay, Mumbai, India, September 2007.

2. Department of Biological Physics, Max Planck Institute for Physics of Complex Systems, Dresden, Germany, October-November 2007.

3. Department of Physics, IIT Kanpur, Kanpur, India, December 2007.

4. Department of Biological Sciences, TIFR, Mumbai, India, February 2008.

Invited Lectures/Seminars:

1. *Noise in Chemotaxis*, Department of Physics, IIT Bombay, Mumbai, September 2007.

2. *Length control of microtubules by depolymerizing molecular motors*, Department of Biological Physics, Max Planck Institute, Dresden, Germany, November 2007.

3. *Signal, noise and response: Stochastic concepts and models in cell signaling*, Department of Biological Sciences, TIFR, Mumbai, February 2008.

4. *Probabilistic modeling in cell biology*, Department of Biological Sciences, TIFR, Mumbai, February 2008.

Other Activities:

1. Delivered a popular talk on 'Physics in Cell Biology' for high school students under the KVPY scheme of DST at HRI (May 2007).

2. Delivered four lectures on 'Physics in Biology' in the HRI Summer School in Condensed Matter Physics(May 2007).

3. Taught the graduate statistical mechanics course at HRI (January-May 2007).

4. Delivered a journal club talk on 'Co-operative interactions in bacterial chemotaxis' (August 2007).

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Rajesh Gopakumar

Research Summary:

In the last year, in work with Suvankar Dutta, we studied the dynamics of weak coupling $U(N)$ Yang-Mills theory at finite temperature. When the gauge theory is in a finite volume it exhibits a number of interesting phases and transitions between them as the temperature is varied. In the context of the AdS/CFT conjecture these have the interpretation as different geometries and transitions between them. We analysed the matrix model for the Polyakov loop which captures the dynamics of the weak coupling model and provided an explicit answer for the partition function for any finite N and temperature. The exact answer is in terms of a sum over representations of $U(N)$ and captures the phase diagram of the gauge theory by exhibiting large N phase transitions. Quantitatively these are captured in terms of a Young Tableau density for the representations. Surprisingly, the large N saddle point configurations of this density together with that of the eigenvalue density for the polyakov loop naturally give rise to a two dimensional fermionic phase space picture for the different saddle points. This may be a useful clue for the holographic reconstruction of the geometry from the gauge theory

In work with Justin David and Ayan Mukhopadhyay, we continued our investigation of the worldsheet duals for gauge theory four point correlation functions. We focussed on a class of correlators in the $\mathcal{N} = \triangle$ super Yang-Mills theory which do not get any corrections as one varies the coupling. Using my earlier proposal for the worldsheet duals of large N gauge theories we found in a particular (semi-classical) limit that the correlation function has support on a one dimensional curve in the two dimensional moduli space of the worldsheet two pint functions. In special cases where this curve can be explicitly characterised we found that it satisfies the expected worldsheet property of crossing symmetry.

We have also been investigating the duals to gauge theory four point functions in the so-called Regge limit of high centre of mass energy but fixed momentum transfer. We hope to be able to understand the localisation of the gauge theory correlation functions from a subspace of the Schwinger parameter space in terms of a worldsheet operator product expansion appropriate to picking out the leading Regge trajectory.

Publications:

1. O. Aharony, J. David, R. Gopakumar, Z. Komargodsky and S. Razamat, *Comments on worldsheet theories dual to free large N gauge theories* Phys. Rev. D. **75**, 106006 (2007).

2. S. Dutta and R. Gopakumar, *Free Fermions and Thermal AdS/CFT* JHEP **0803**, 011 (2008).

Conference/Workshops Attended:

1. Solvay workshop on Gauge theory, String Theory and Geometry, Brussels, May 2007
2. XXVIII Brazilian National Meeting of Particles and Fields, Aguas de Lindoia, Sep. 2007
3. Indian Strings Meeting ISM07, HRI, Allahabad, Oct. 2007

Visits to other Institutes:

1. IISER, Kolkata, Apr. 2007.
2. TIFR, Mumbai, May 2007.
3. ASICTP, Trieste, Italy, Aug. 2007.
4. Institute for Theoretical Physics, IFT, Sao Paulo, Sep. 2007.

Invited Lectures/Seminars:

1. *Mini course on Extremisation Principles in Physics* IISER Kolkata, Apr. 2007 (contd. from Feb, Mar.).
2. *Comments on the Worldsheet Duals of Free Large N Gauge Theories.* Solvay workshop on Gauge theory, String Theory and Geometry, Brussels, May 2007.
3. *ICTP Prize Lecture*, ASICTP, Trieste, Aug. 2007.
4. *String Seminar* From Fermions to AdS ASICTP, Trieste, Aug. 2007.
5. *Four Lecture Series Gauge-String Duality*, IFT, Sao Paulo, Sep. 2007.
6. *Plenary talk, XXVIII Brazilian National Meeting of Particles and Fields,* Aguas de Lindoia, Sep. 2007.
7. *Free Fermions and Thermal AdS/CFT* Indian Strings Meeting ISM07, HRI, Allahabad, Oct. 2007.

Other Activities:

1. Guided four VSP students, Jul./Oct./Dec. 2007.
2. Member, International Organising Committee, ICGC-Pune (Dec. 2007).
3. Member of various administrative committees.

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Srubabati Goswami

Research Summary:

Symmetry-based ideas, such as the quark-lepton complementarity (QLC) principle and the tri-bimaximal mixing (TBM) scheme, have been proposed to explain the observed mixing pattern of neutrinos. We argue that such symmetry relations need to be imposed at a high scale $\Lambda \sim 10^{12}$ GeV characterizing the large masses of right-handed neutrinos required to implement the seesaw mechanism. For nonhierarchical neutrinos, renormalization group evolution down to a laboratory energy scale $\lambda \sim 10^3$ GeV tends to radiatively break these symmetries at a significant level and spoil the mixing pattern predicted by them. However, for Majorana neutrinos, suitable constraints on the extra phases $\alpha_{2,3}$ enable the retention of those high scale mixing patterns at laboratory energies. We examine this issue within the Minimal Supersymmetric Standard Model (MSSM) and demonstrate the fact posited above for two versions of QLC and two versions of TBM. The appropriate constraints are worked out for all these four cases. Specifically, a preference for $\alpha_2 \approx \pi$ (i.e. $m_1 \approx -m_2$) emerges in each case. We also show how a future accurate measurement of θ_{13} may enable some discrimination among these four cases in spite of renormalization group evolution.

We study the problem of determination of the sign of the atmospheric mass squared difference or the neutrino mass hierarchy through observations of atmospheric neutrinos in future detectors. We consider two proposed detector types : a) Megaton sized water Cherenkov detectors, which can measure the survival rates of $\nu_\mu + \bar{\nu}_\mu$ and $\nu_e + \bar{\nu}_e$ and b) 100 kton sized magnetized iron detectors, which can measure the survival rates of ν_μ and $\bar{\nu}_\mu$. For energies and path-lengths relevant to atmospheric neutrinos, these rates obtain significant matter contributions from $P_{\mu e}$, $P_{\mu\mu}$ and P_{ee}, leading to an appreciable sensitivity to the hierarchy. We do a binned χ^2 analysis of simulated data in these two types of detectors which includes the effect of smearing in neutrino energy and direction and incorporates detector efficiencies and all relevant statistical, theoretical and systematic errors. We also marginalize the χ^2 over the allowed ranges of neutrino parameters in order to accurately account for their uncertainties. Finally, we compare the performance of both types of detectors vis a vis the hierarchy determination.

The MiniBooNE and LSND experiments are compatible with each other when two sterile neutrinos are added to the three active ones. In this case there are eight possible mass orderings. In two of them both sterile neutrinos are heavier than the three active ones. In the next two scenarios both sterile neutrinos are lighter than the three active ones. The remaining four scenarios have one sterile neutrino heavier and another lighter than the three active ones. We analyze all

scenarios with respect to their predictions for mass-related observables. These are the sum of neutrino masses as constrained by cosmological observations, the kinematic mass parameter as measurable in the KATRIN experiment, and the effective mass governing neutrinoless double beta decay. It is investigated how these non-oscillation probes can distinguish between the eight scenarios. We also remark on scenarios with three sterile neutrinos. In addition we make some comments on the possibility of using decays of high energy astrophysical neutrinos to discriminate between the mass orderings in presence of two sterile neutrinos.

We have explored the effect of non-unitary neutrino mixing on neutrino oscillation probabilities both in vacuum and matter. In particular, we consider the $\nu_\mu \to \nu_\tau$ channel using a Neutrino Factory as the source for ν_μ's and discuss the constraints that can be obtained on the moduli and phases of the parameters characterizing the violation of unitarity. We point out how the new CP violation phases present in the case of non-unitary mixing give rise to spurious "degenerate" solutions in the parameter space and discuss how the true solutions can be extricated by combining measurements at several baselines.

Publications:

1. R. Gandhi, P. Ghoshal, S. Goswami, P. Mehta, S. U. Sankar and S. Shalgar, Mass Hierarchy Determination via future Atmospheric Neutrino Detectors , Phys. Rev. D **76**, 073012 (2007).

2. S. Goswami and W. Rodejohann, *MiniBooNE Results and Neutrino Schemes with 2 sterile Neutrinos: Possible Mass Orderings and Observables related to Neutrino Masses* , JHEP, **0710**, 073 (2007).

3. A. Dighe, S. Goswami and P. Roy, *Radiatively broken symmetries of nonhierarchical neutrinos*, PHYS. REV. D, **76**, 096005 (2007).

Preprints:

1. Srubabati Goswami and Toshihiko Ota, *Testing Non-Unitarity of Neutrino Mixing Matrices at Neutrino Factories, arXiv:0802.1434* (to appear in Physical Review D)

2. *Physics at a future Neutrino Factory and Super-beam facility , by ISS Physics Working Group, eprint:arXiv:0710.4947*

Conference/Workshops Attended:

1. *Workshop in High Energy Physics Phenomenology, IMSC, Chennai, India, January, 2008*.

2. *Nu-Horizons*, HRI, Allahabad, India, February 2008.

Visits to other Institutes:

1. Max–Planck–Institut für Kernphysik, Heidelberg, Germany, May-June 2007.
2. Tata Institute of Fundamental Research, June 2008, October 2008.

Invited Lectures/Seminars:

1. *Present Horizons of Neutrino Masses and Mixing* , , NuHorizons, HRI, February 2008.

   Dawn of a Nu Era, Dr. P. Sheel Memorial Lecture award, , NASI, Allahabad, March 2008.

Other Activities:

1. Partially supervised thesis work of Pomita Ghoshal.
2. Refereed papers for Physical Review D, Advances in High Energy Physics.
3. Guided project students Sushant Raut and Ravishankar Singh.
4. Taught the particle Physics course for the semester -III.
5. Convener for the Nu-HoRIzon conference organized at HRI under the Neutrino Project in the XIth plan.
6. Principal Investigator for the project "Neutrinos and the fundamental Laws of Physics" under the UK-India Research initiative (UKIERI).
7. Served in the Transport Committee (as convener) and Local Works Committee (as member).

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Bindu S. Govindan

Research Summary:

Mitotic-centromere-associated kinesins (MCAK) are one class of kinesin motor proteins which have been shown to be important in the formation of the metaphase spindle, the structure formed by microtubules prior to seggregation of chromosomes during cell division. *In vitro* studies have also shown that MCAK act as depolymerizing agents for microtubules. We formulated a stochastic model of depolymerization of microtubules by MCAK by tip-accumulation following non-specific surface binding. It is shown that the length distribution of microtubules in the presence of MCAK is strongly non-monotonic, which is consistent with its role in spindle formation. Other experimental observations like the length-dependence of depolymerization rate is also consistent with he model (in collaboration with Manoj Gopalakrishnan and Debashish Chowdhury).

Chromosome segregation is accomplished through the formation of the *mitotic spindle* structure, in which microtubules nucleate from the two centrosomes located at two opposite poles of the dividing cell, and by the process of dynamic instability, scan the surrounding cytoplasmic space for chromatid pairs, released following the nuclear envelope breakdown (anaphase). Can successful chromosome search and capture be accomplished purely through the random three-dimensional search by microtubules, or are additional 'guiding mechanisms' necessary in order to make sure that microtubules would preferentially grow towards the chromosomes? A stochastic description of this process using appropriately defined Green's functions for microtubule kinetics has been formulated to study this problem. Preliminary results are in agreement with existing numerical simulations (by other authors) and significant progress is expected in the coming months (work in collaboration with Manoj Gopalakrishnan).

Publications:

1. B.S. Govindan, M. Gopalakrishnan and D.Chowdhury *Length control of microtubules by depolymerizing molecular motors,* Euro. Phys. Lett. (To appear) (2008)

Preprints:

1. B.S. Govindan, M. Gopalakrishnan and D.Chowdhury *MCAK Selectively targets long microtubules for depolymerization, ICTP preprint* IC/2007/060

2. M.Gopalakrishnan and B.S. Govindan, *Stochastic model of microtubules searching for fixed targets in space* (in preparation)

Visits to other Institutes:

1. The Abdus Salam International Center for Theoretical Physics, Trieste, Italy, June 2007.

2. Max-Planck Institute for Physics of Complex Systems, Dresden, Germany, October1-November 15, 2007.

Other Activities:

1. Delivered journal club talk on 'Co-operative cargo transport by several molecular motors', September 2007.

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Rajesh Kumar Gupta

Research Summary:

I am working on black holes in string theory and Ads/CFT correspondance. During this academic year I have studied three dimensional (super-)gravity and Ads3/CFT2 correspondance. In this case I with Prof. Ashoke Sen derived the central charge of the two dim. boundary CFT which is dual to three dim. bulk theory with arbitrary local higher derivative terms.

I have also studied Ads5/CFT4 correspondance.

Publications:

1. Rajesh Kumar Gupta, Ashoke Sen, *Consistent Truncation to Three Dimensional (Super-)gravity*, JHEP **0803**, 22, (2008)

Conference/Workshops Attended:

1. *Indian String Meeting* , India, October, 2007

Invited Lectures/Seminars:

1. *Consistent Truncation to Three Dim. (Super-)gravity*, Indian String Meeting, Harish-Chandra Research institute, Allahabad, October 2007.

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Sudhir Kumar Gupta

Research Summary:

During this academic year we studied the following problems:

- **Distinguishing between Supersymmetry and Little Higgs Models**

  As an special case we studied, the possibility of distinguishing T-parity conserving Little Higgs model with R-parity conserving Supersymmetry in *hadronically-quiet-trileptons* signals at the Large Hadron Collider (LHC). We identified the regions of the parameter space where such signals can reveal the presence of these new physics models above the Standard Model background and distinguish them from each other, even in a situation when the mass spectrum of the Littlest Higgs model resembles the supersymmetric pattern.

  collaborators *AseshKrishna Datta, Paramita Dey, Sudhir Kumar Gupta and Biswarup Mukhopadhyaya*

- **Stop Tracks at the LHC** As a follow up of our study on stau NLSP in previous year, we studied the consequences of a stop NLSP scenario also in the same line. If the (lighter) stop is the NLSP, it will decay into the right sneutrino LSP through three body decays. The major decay of the stop NLSP will be in to a b-quark, a tau and a right sneutrino (LSP). Here, too, because of the smallness of neutrino Yukawa coupling the stop will decay outside of the detector and hence leave its imprints in the form of 'colored' tracks. In a minimal supergravity (with non-universal third generation sfermion masses) motivated model, we studied the signals arising due to such an stop NLSP, by specifically looking signatures with two and one stop-tracks. We found that there are large number of events in a few month of LHC data. We also found that the reconstruction of gluino is possible in such a scenario with a rather higher amount of integrated luminosity.

  Collaborators *Debajyoti Choudhury, Sudhir Kumar Gupta and Biswarup Mukhopadhyaya*

- **Direct-detection of Dark Matter** Presently, we are working on the possibility of detecting the dark matter candidates of new physics models in Dark matter detection experiments such as CDMS, CRESSET, DAMA and EDELWEISS. The underlying principle of all these experiments are the scattering of dark matter candidates with material. We have done some primary checks using micrOMEGAS for the neutralino dark matter in minimal-Supergravity case.

Collaborators*Paramita Dey, Sudhir Kumar Gupta and Biswarup Mukhopadhyaya*

Publications:

1. Right-chiral sneutrinos and long-lived staus: Event characteristics at the large hadron collider, *Sudhir Kumar Gupta, Biswarup Mukhopadhyaya, Santosh Kumar Rai*, Phys.Rev.**D75** (075007) [hep-ph/0701063].

2. Distinguishing the Littlest Higgs model with T-parity from supersymmetry at the LHC using trileptons, *AseshKrishna Datta, Paramita Dey, Sudhir Kumar Gupta, Biswarup Mukhopadhyaya, Andreas Nyffeler*, Phys.Lett. **B659** (308) [arXiv:0708.1912 [hep-ph]].

Preprints:

1. Right sneutrinos in a supergravity model and the signals of a stable stop at the Large Hadron Collider, *Debajyoti Choudhury, Sudhir Kumar Gupta, Biswarup Mukhopadhyaya*, [arXiv:0804.3560 [hep-ph]].

2. P.Dey, S.K. Gupta, B. Mukhopadhyaya, *The T-odd neutrino of Littlest Higgs Model with T-parity as a dark-matter,* (in preparation).

Conference/Workshops Attended:

1. *RECAPP-QCD School* at HRI, Allahabad (India), November'07.

2. *X^{th} Workshop on High Energy Physics Phenomenology* at Institute of Mathematical Sciences, Chennai (India), January'08.

3. *Nu Horizons: Neutrinos in Physics, Astrophysics, and Cosmology* at HRI, Allahabad (India), February'08.

Visits to other Institutes:

1. Dept of Physics and Astronomy, University of Glasgow, Glasgow, (Scotland), October'07.

2. Institute of Particle Phenomenology, University of Durham, Durham (England), October'07.

3. SHEP, Dept of Physics and astrophysics, University of Southampton, Southampton (England), October'07.

4. Dept. of Physics, University of Manchaster, Manchaster (England), October'07.

5. Dept of Physics, University of Wurezburg, Wuerzburg (Germany), October'07.

6. Laboratory of particle physics, Annecy (France), October'07.

7. Physics Dept., University of Bonn, Bonn (Germany), November'07.

8. Physics Dept., Technical University (RWTH) of Aachen, Aachen (Germany), October'07.

9. Department of Theoretical Physics, Tata Institute of Fundamental Research, Mumbai(India), December'07.

Invited Lectures/Seminars:

1. *Z_3 Symmetry and Neutralino Dark Matter*, HRI, Allahabad (India), August'07.

2. Gave seminars on "*Long Lived Charged Tracks at the LHC*" and "*Split Supersymmetry at colliders*" on all the Institutes visited during October-December'07 (Total = 9).

3. *Some Studies on Supersymmetry Search in Accelerators*, HRI, Allahabad (India) April'07.

Academic recognition/Awards:

- Awarded Post-doctoral Fellowship by Tata Institute of Fundamental Research, Mumbai (India) (2008).

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Rajeev Kumar Jain

Research Summary:

During the last year, my research work has been focussed on investigating the following two issues in inflationary cosmology and reheating:

1. Deviations from slow roll inflation and generation of features in the primordial spectrum

2. Reheating and its effects on the evolution of curvature perturbations

I have briefly described below these two issues.

1. *Deviations from slow roll inflation and generation of features in the primordial spectrum:* In this work, we investigate inflationary scenarios driven by a class of potentials motivated by certain minimal supersymmetric extensions of the standard model. We show that these potentials allow a period of deviation from inflation sandwiched between two stages of slow roll inflation. We find that the modes which exit the Hubble radius during the period of fast roll have lower power when compared to the amplitude of the nearly scale invariant spectrum associated with the modes that leave during the second stage of slow roll inflation. We set the scales such that the dip in the scalar power spectrum corresponds to the Hubble scale today–a feature that seems necessary to explain the lower power observed in the quadrupole moment of the cosmic microwave background. We perform a Markov Chain Monte Carlo analysis to determine the values of the model parameters that provide the best fit to the recent five-year WMAP data. We find that the inflationary spectra with a suppression of power at large scales that we obtain lead to a better fit (χ^2 improves by about 6) of the observed data when compared to the standard power law spectrum. We also comment on the effects on the corresponding tensor power spectrum.

2. *Reheating and its effects on the evolution of curvature perturbations:* We investigate the problem of reheating as well as its effects on the evolution of the curvature perturbations in Dirac-Born-Infeld (DBI) inflationary models. We derive the equations governing the evolution of the scalar perturbations for a system consisting of a DBI scalar field and a perfect fluid. Assuming the perfect fluid to be radiation, we solve the set of dynamical equations for the system numerically and study the evolution of large scale curvature perturbations during reheating. In particular, we study the effects of the transition from inflation to the radiation dominated epoch on the evolution of the curvature, the entropy and the isocurvature perturbations. We also discuss the effects of reheating on the spectrum of curvature perturbations of the system.

Publications:

1. Rajeev Kumar Jain, P. Chingangbam and L. Sriramkumar, *On the evolution of tachyonic perturbations at super-Hubble scales,* Journal of Cosmology and Astroparticle Physics **10**, 003 (2007).

2. Nabamita Banerjee, Rajeev Kumar Jain and Dileep P. Jatkar, *Non-gravitating scalar field in the FRW background,* General Relativity and Gravitation **40**, 93 (2008).

Conferences/Workshops Attended:

1. *Training programme in Linux System and Network Administration*, Harish-Chandra Research Institute, Allahabad, India, May 14-19, 2007.

2. *IPM Cosmology School and Workshop*, Institute for Studies in Theoretical Physics and Mathematics, Tehran, Iran, June 2-9, 2007.

3. *IIA-Penn State Astrostatistics School*, Vainu Bappu Observatory, Kavalur, India, July 2-7, 2007.

4. *Indian Conference on Cosmology and Galaxy Formation*, Harish-Chandra Research Institute, Allahabad, India, Nov 3-5, 2007.

5. *Field Theoretic Aspects of Gravity VI*, Harish-Chandra Research Institute, Allahabad, India, Nov 13-17, 2007.

6. *International Conference on Gravitation and Cosmology*, Inter-University Centre for Astronomy and Astrophysics, Pune, India, Dec 17-21, 2007.

7. *The Tenth Workshop on High Energy Physics Phenomenology*, Institute of Mathematical Sciences, Chennai, India, Jan 2-13, 2008.

8. *Prospects and Problems of Gravitation and Cosmology*, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, India, Jan 29-30, 2008.

Visits to other Institutes:

1. Inter-University Centre for Astronomy and Astrophysics, Pune, India, Feb 27-April 5, 2008.

Invited Lectures/Seminars:

1. *Amplification of tachyonic perturbations at super-Hubble scales*, IPM Cosmology School and Workshop, Institute for Studies in Theoretical Physics and Mathematics, Tehran, Iran, June 2-9, 2007.

2. *On the evolution of curvature perturbations at super-Hubble scales*, Field Theoretic Aspects of Gravity VI, Harish-Chandra Research Institute, Allahabad, India, Nov 13-17, 2007.

3. *Non-gravitating scalar field in the FRW background*, International Conference on Gravitation and Cosmology, Inter-University Centre for Astronomy and Astrophysics, Pune, India, Dec 17-21, 2007.

Other Activities:

1. Astrophysics Journal Club Talk

   (a) *Constraints on features in the primordial spectrum of inflationary perturbations*, Journal Club Talk, May, 2007.

   (b) *Evolution of large scale curvature fluctuations during the decay of inflaton*, Journal Club Talk, Sep, 2007.

2. Astrophysics Seminar

   (a) *Amplification of tachyonic perturbations at super-Hubble scales*, Astrophysics Seminar, April, 2007.

3. Helped in organizing and evaluating the papers (Physics) of HRI Science Talent Test 2007.

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Harvinder Kaur Jassal

Research Summary:

Accelerated expansion of the universe requires either a cosmological constant or some form of dark energy to drive the acceleration. Although a cosmological constant is a simpler solution from a phenomenological point of view, there is no natural explanation of the small observed value. This has inspired theorists to develop toy models where a field, typically a scalar field provides the source of dark energy. All such models require fine tuning in order to ensure transition to a dark energy dominated universe at $z \sim 0.5$. A distinctive feature of these models as compared to the cosmological constant is that the equation of state changes with time and it is in general different from -1. In absence of significant spatial variations in these fields, this is the only difference between cosmological constant and other models of dark energy. Current observations do not rule out $w = -1$, thus observational evidence for a varying equation of state will be of great significance.

If dark energy is not a cosmological constant it has to cluster. This is in accordance with the weak energy principle. The perturbations in dark energy can affect growth of large scale structures in the universe. We consider different models of dark energy for studying evolution of perturbations. Even if the scale factor evolves in a similar manner for different models of dark energy, the perturbations may evolve in an entirely different manner. We estimate the amplitude of the perturbation in dark energy at different length scales for a quintessence model with an exponential potential. We show that on length scales much smaller than hubble radius, perturbations in dark energy are negligible in comparison to the perturbations in dark matter. However, on scales comparable to the hubble radius ($\lambda_p > 1000\mathrm{Mpc}$) the perturbation in dark energy in general cannot be neglected. In fact the effect of dark energy perturbations on matter perturbations is large and can have observable significance. As compared to the ΛCDM model, large scale matter perturbations are suppressed in generic dark energy models.

Publications:

1. Jassal H. K. and Sriramkumar L., *Entropy of BTZ black strings in the brick wall approach*, Class. Quant. Grav. 24, 2589 (2007).

Preprints:

1. Unnikrishnan S., Jassal H. K. and Seshadri T. R., *Scalar Field Dark Energy Perturbations and their Scale Dependence*, arXiv:0801.2017 [astro-ph].

Conference/Workshops Attended:

1. *Indo-Brazil Workshop on Cosmology*, IUCAA, India, July, 2007.
2. *Indian Conference on Cosmology and Galaxy Formation*, IUCAA, India, November, 2007.
3. *Field Theoretic Aspects of Gravitation*, HRI, India, November, 2007.
4. *International Conference on Gravitation and Cosmology*, IUCAA, India, December, 2007.
5. *Prospects and Problems of Gravitation and Cosmology*, Jamia Millia Islamia, India, January, 2008.

Visits to other Institutes:

1. Raman Research Institute, Bangalore, India, February-March 2008.

Invited Lectures/Seminars:

1. *Dark Energy : Theoretical and Observational Issues*, Invited talk, in meeting on *Prospects and Problems of Gravitation and Cosmology*, Jamia Millia Islamia, India, January, 2008.
2. *Theoretical and Observational aspects of Dark Energy*, Seminar, R. R. I., Bangalore, March 2008.

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Dileep P. Jatkar

Research Summary:

I continued studying dyon spectrum in $\mathcal{N} = 4$ supersymmetric string compactifications. With N. Banerjee and A. Sen we generalized the dyon configuration studied while determining their degeneracy to arbitrary electric and magnetic charge. The four dimensional $\mathcal{N} = 4$ supergravity actions cleverly adjust themselves to accommodate new charges and at the same time maintaining the degeneracy formula.

Publications:

1. N. Banerjee, D. P. Jatkar and A. Sen, *Adding charges to N=4 dyons,* JHEP **0707**, 024, (2007)

2. N. Banerjee, R. K. Jain and D. P. Jatkar, *Non-Gravitating Scalar Field in the FRW Background.,* Class. Quant. Gravity **40**, 93, (2008)

Conference/Workshops Attended:

1. *Strings 2007*, Spain, June 2007.

2. *National String Workshop*, India, October 2007.

3. *From Strings to LHC-II*, India, December 2007.

4. *Beyond Standard Model*, India, March 2008.

Invited Lectures/Seminars:

1. *Variations of KKLT Scenario*, Beyond Standard Model, CHEP, Bangalore, March 2008.

Other Activities:

1. Organized National String Workshop at HRI, October 2007.

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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 surveys will reveal much on the formation of structures at these scales. To understand structure formation and make proper predictions for these surveys one requires N-body algorithms which are not only accurate and efficient but have a large dynamic range.

- *N-body Simulations*:

  We have successfully implemented optimisations on the existing TreePM algorithm of Bagla,J.S. (JAA,2002) by incorporating a multiple timestep integrator with with Barnes optimisation (JCompPh, 1990) using $groups$. The net speedup with these two optimisations has been around $10 - 15$.

  Current $N-$Body codes suffer either from force anisotropy or collisionality at small scales. In order to address both issues we have developed the Adaptive TreePM (ATreePM) code which addresses the issue of collisionality in TreePM. This was done by using individual softening lengths for particles.

  In recent times the development of new CPUs has focussed on slower multicore processors instead of faster single ones. We have successfully parallelised our $N-$body code in a shared+distributed memory setup using OpenMP+MPI to better adapt to this new trend in CPU development.

  Our code has been used in two recent works:

  arXiv:astro-ph/0802.2796v1
  arXiv:astro-ph/0804.1197v2

- $Gravitational\ Clustering$

  We are currently working on verifying the Stable Clustering (SC) ansatz using $N-$body simulations. Many studies have been carried out in the past but none have been conclusive. We hope to make definitive comments on SC using our $N-$body code.

We are also looking at getting insights from $N-$ body simulations to truncate the BBGKY hierarchy as to better comment on the consistency of SC with other ansatz.

N-body simulations seem to indicate that dark matter halos seem to be having a universal profile. The reason for this universality is not known but the nature of the profiles has been of much debate. Since ATreePM will guarantee collisionless evolution at small scales we hope to shed some light on density profiles.

Preprints:

1. Nishikanta Khandai, J.S. Bagla, *A Modified TreePM Code,* arXiv:astro-ph/0802.3215v2

2. J.S. Bagla, Jayanti Prasad, Nishikanta Khandai, *Effects of the size of cosmological N-Body simulations on physical quantities - III: Skewness,* (In Preparation)

3. J.S. Bagla, Nishikanta Khandai, *Adaptive TreePM, A High Resolution Collisionless Code for Cosmological N-body Simulations - I: Formalism and Preliminary Results,* (In Preparation)

Conference/Workshops Attended:

1. *Linux System and Network Administration, Linux learning Centre, HRI*, India, May 2007.

2. *School on Astrophysical Fluid Dynamics, ICTP*, Italy, October 2007.

3. *Indian Conference on Cosmology and Galaxy Formation, HRI*, India, November 2007.

4. *International Conference in Gravitation and Cosmology, IUCAA*, India, December 2007.

Invited Lectures/Seminars:

1. *Modified TreePM, A High Resolution Collisionless Code for Cosmological N-Body Simulations*, School on Astrophysical Fluid Dynamics ICTP, Italy, October 2007.

2. *Optimising The TreePM Code*, Indian Conference on Cosmology and Galaxy Formation, HRI, Allahabad, India, November 2007.

3. *Towards Optimal N-Body Codes*, International Conference in Gravitation and Cosmology, IUCAA, Pune, India, December 2007.

Other Activities:

1. Tutor for Electrodynamics Course, Semester - 1, 2007.

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Girish Pramod Kulkarni

Research Summary:

My work in the last academic year has been focused on the theme of cosmic reionization. We studied the halo model of structure formation and have been working on trying to constrain the physics of star formation by using observations related to reionization. A publication summarising our conclusions in under preparation.

Conference/Workshops Attended:

1. *Indian Conference on Cosmology and Galaxy Formation*, India, November, 2007.
2. *International Conference on Gravitation and Cosmology*, India, December, 2007.

Visits to other Institutes:

1. Inter-University Center for Astronomy and Astrophysics, Pune, India, December 2007.
2. Raman Research Institute, Bangalore, India, March 2008.

Invited Lectures/Seminars:

1. *Effects of features in power spectrum at non-linear scales*, Inter-University Center for Astronomy and Astrophysics, Pune, December 2007.

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Swarup Kumar Majee

Research Summary:

My current research interest lies on the topic of Universal Extra Dimension (UED), Supersymmetry Higgs search and Supersymmetric Grand Unified Theory in high energy particle physics. During 2007-08, I have worked on the following topics –

(1) **Extra-dimensional relaxation of the upper limit of the lightest supersymmetric neutral Higgs mass**
Collaborators: Gautam Bhattacharyya, Amitava Raychaudhuri
The upper limit on the mass of the lightest CP-even neutral Higgs in the minimal supersymmetric standard model is around 135 GeV for soft supersymmetry breaking masses in the 1 TeV range. We demonstrate that this upper limit may be sizably relaxed if supersymmetry is embedded in extra dimensions. We calculate, using the effective potential technique, the radiative corrections to the lightest Higgs mass induced by the Kaluza-Klein towers of quarks and squarks with one and two compactified directions. We observe that the lightest Higgs may comfortably weigh around 200 GeV (300 GeV) with one (two) extra dimension(s).

(2) $SU(6)$**, Triquark states, and the pentaquark**
Collaborators: Amitava Raychaudhuri
The purported observation of a state Θ^+ with strangeness S = +1 led to its quark model interpretation in terms of a pentaquark combination involving a triquark-diquark structure – the Karliner-Lipkin model. In this work, the proper colour-spin symmetry properties for the $qq\bar{q}$ triquark are elucidated by calculating the SU(6) unitary scalar factors and Racah coefficients. Using these results, the colour-spin hyperfine interactions, including flavour symmetry breaking therein, become straight-forward to incorporate and the pentaquark masses are readily obtained. We examine the effect on the pentaquark mass of (a) deviations from the flavour symmetric limit and (b) different strengths of the doublet and triplet hyperfine interactions. Reference values of these parameters yield a Θ^+ mass prediction of 1601 MeV but it can comfortably accommodate 1540 MeV for alternate choices. In the same framework, other pentaquark states Ξ (S=–2) and Θ^c (with charm C=–1) are expected at 1783 MeV and 2757 MeV, respectively.

Publications:

1. Gautam Bhattacharyya, Swarup Kumar Majee, Amitava Raychaudhuri, *Extra-dimensional relaxation of the upper limit of the lightest supersymmetric neutral Higgs mass,* Nuclear Physics **B793**, 114-130, (2008)

2. Swarup Kumar Majee, Amitava Raychaudhuri, $SU(6)$*, Triquark states, and*

the pentaquark, Physical Review **D77**, 074016, (2008)

Conference/Workshops Attended:

1. *Workshop on Grand Unification and Proton Decay*, Italy, July, 2007.
2. *Indian Physics Society Young Physicists Colloquium 2007*, India, August, 2007.
3. *School on QCD at LHC*, India, November, 2007.
4. *Higgs Hunters' Meeting*, India, February, 2008.
5. *Nu HoRIzons 2008* , India, February, 2008.
6. *Physics of Warped Extra-Dimensions 2008*, India, February, 2008.

Visits to other Institutes:

1. University of Calcutta, Kolkata, India, September, 2007.
2. Saha Institute of Nuclear Physics, Kolkata, India, March, 2008.

Invited Lectures/Seminars:

1. *Can we have a low intermediate scale?*, Harish-Chandra Research Institute, Allahabad, April, 2007.
2. *Low intermediate scale for leptogenesis in supersymmetric SO(10) Grand Unified Theory*, Indian Physics Society Young Physicists Colloquium 2007, Kolkata, India, August, 2007.
3. *Some Explorations of New Physics Beyond The Standard Model*, University of Calcutta, Kolkata, September, 2007.
4. *Relaxation of the upper limit of the LSNH mass in the Extra-Dimensional Scenario*, Higgs Hunter Meeting, Visva-Bharati, Santiniketan, February, 2008.
5. *Relaxation of the upper limit of the LSNH mass in the Extra-Dimensional Scenario*, PWED'08, Indian Institute of Technology Kharagpur, Kharagpur, February, 2008.
6. *Lightest Supersymmetric Neutral Higgs in the Extra-Dimensional Scenario*, Saha Institute of Nuclear Physics, Kolkata, March, 2008.

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Pinaki Majumdar

Research Summary:

I have worked on (i) exploring the effect of strong scatterers in the manganites, (ii) the field induced melting of charge order and associated hysteresis in these materials, and (iii) have started on a comprehensive project for understanding the structural order and magnetism in the double perovskites. There is also an on-going project for implementing a cluster dynamical mean field theory (C-DMFT) calculation for correlated systems.

Publications:

1. Kalpataru Pradhan, Anamitra Mukherjee, and Pinaki Majumdar, *Distinct Effects of Homogeneous Weak Disorder and Dilute Strong Scatterers on Phase Competition in the Manganites,* Phys. Rev. Lett. **99**, 147206 (2007)

2. K. Sengupta, N. Dupuis, and P. Majumdar, *Bose-Fermi Mixtures in an Optical Lattice,* Phys. Rev. **A 75**, 063625 (2007)

Preprints:

1. Kalpataru Pradhan, Anamitra Mukherjee and Pinaki Majumdar, *Exploiting B Site Disorder for Electronic Phase Control in the Manganites,* arXiv:0710.2278

2. Anamitra Mukherjee, Kalpataru Pradhan and Pinaki Majumdar, *Hysteresis and Inhomogeneous Melting in the Field Response of Half Doped Charge Ordered Manganites,* arXiv:0801.2054

3. Prabuddha Sanyal, Sabyasachi Tarat and Pinaki Majumdar, *Structural Ordering and Antisite Defect Formation in Double Perovskites,* arXiv:0804.1681

Conference/Workshops Attended:

1. *Indo-Japan Meeting on Multiferroics*, IACS, Kolkata, India, Feb 2008.

Invited Lectures/Seminars:

1. *Interactions and disorder in correlated systems*, Institute Colloquium, SINP, Kolkata, Aug 2007.

2. *B site disorder in the manganites*, Indo-Japan meeting, IACS, Kolkata, Feb 2008.

Academic recognition/Awards:

- S. S. Bhatnagar Award in Physical Sciences, 2007.

Other Activities:

1. Organised a Summer School at HRI on Condensed Matter Physics/Materials Theory for B.Sc/M.Sc students, with Prasenjit Sen. Gave 6 lectures at the School. May 2007.

2. Lecturer: School on Computational Many Body Methods, at JNCASR, Bangalore, Oct 2007.

3. Interviewer for KVPY interviews, Dec 2007 at HRI.

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Manimala Mitra

Research Summary:

At present my research interest is on neutrino mass model , cp violation and on leptogenesis. I've completed one work on neutrino mass model.The model is based on some extra discrete symmetry group A_4 in addition to the standard model gauge group.Standard model cannot predict neutrino mass, but neutrino oscillation experiments strongly point towards neutrino mass, though small. This extra discrete symmetry can successfully predicts majorana mass for neutrino. In the paper , *A_4 flavor symmetry and neutrino phenomenology,* Phys.Rev.D 77 , 073008, (2008) we have explored this idea.We have written a most general yukawa lagrangian and explored the different possibilities of majorana mass generation.We have also done a detail analysis on parameter space and also calculated the predictions(observables) of this model. This model predicts tri-bimaximal mixing in leptonic sector which is in a very good agreement with the experimental results of the oscillation parameters.We have also shown how much deviation from the TBM mixing constraints one can allow so that the predictions about three mixing angle and mass squared differences fall into 3σ allowed intervals.

Publications:

1. Manimala Mitra,Sandhya Choubey,Biswajoy Brahmachari, *A_4 flavor symmetry and neutrino phenomenology,* Phys.Rev.D 77 , 073008, (2008).

Preprints:

1. Manimala Mitra,Sandhya Choubey,Biswajoy Brahmachari, *A_4 flavor symmetry and neutrino phenomenology ,* arXiv:0801:3554.

Conference/Workshops Attended:

1. *Penn State Astrostatistics School*,Vainu Bappu Observatory,Kavalur,India,July 2007.

2. *SERC school-2008*, IITB,Mumbai,India, February, 2008.

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Ayan Mukhopadhyay

Research Summary:

I have been involved with two projects in this academic year and both of them are related to gauge/gravity duality. Gauge/gravity duality (anticipated by 'thooft) is one of the predictions of string theory which says that four dimensional gauge theories may be described using five dimensional gravity theory with a precise map translating observables on one side to the other. My first project concerns the regime where the gauge theory is free. In this regime there has been a proposal due to Rajesh Gopakumar which gives a precise prescription of constructing the worldsheet correlators of the string theory which are dual to the gauge theories with matter in the adjoint representation. In the gauge/gravity dictionary with every gauge invariant operator there corresponds a particle/state in the five dimensional theory of gravity and any spacetime correlator of gauge invariant operators is interpreted as an on-shell S-matrix of particle scattering in the five-dimensional spacetime. An S-matrix in string theory is obtained by integrating over worldsheets, so every spacetime correlator of gauge invariant operators could be rewritten as an integral of worldsheet correlators over the moduli space of Riemann surfaces. Gopakumar's proposal gives a way of constructing these worldsheet correlators. In collaboration with Rajesh Gopakumar and Justin David, I have studied the case in which the particles in five dimensional theory are ultramassive, or, by the dictionary, the operators in gauge theory have large mass dimensions. In particular we have studied gauge theory correlators of the form $< Tr(Z^{J_1}(x))Tr(Z^{J_2}(y))Tr(Z^{J_3}(z))Tr(\overline{Z}^{J}(w))) >$, where Z is an adjoint scalar, $J = J_1 + J_2 + J_3$ and we have taken all J's to be large with the ratios between them held fixed. We find that we have to sum over the contributions from a family of diagrams (which we call lollipop diagrams) and in our limit the contribution to the worldsheet correlator is localised on a curve in the moduli space. This behaviour is in sharp contrast with high energy string scattering in flat space studied by Gross and Mende earlier in which the contribution was localised at a single point in the moduli space. We have explicitly solved the worldsheet correlator in a special case and demonstrated that when the contributions from all the lollipop diagrams are summed up our worldsheet correlator satisfies another consistency test, that of crossing symmetry. In the case of $\mathcal{N} = 4$ SYM theory, it is known that the planar gauge theory correlators we have studied, are not renormalised. We have argued that this would imply that our worldsheet correlator would also be uncorrected even when the gauge theory becomes strongly coupled. This allows us to make certain interesting predictions about high energy classical string scattering in $AdS_5 \times S^5$ space. If these predictions are verified, they would strongly indicate that the dual string theories of free gauge theories which

we have constructed would smoothly interpolate to the conventional string theories living on geometric backgrounds when the gauge theory becomes strongly coupled.

My second project, which is still in progress involves the other regime of gauge/ gravity duality, the regime where the gauge theory is strongly coupled and the rank of the gauge group is large, so that the theory of five dimensional gravity is well described by classical supergravity. If the gauge theory is conformal then the corresponding asymptotics of the five dimensional gravity theory should be that of AdS. The equations of motion of supergravity irrespective of the matter content always admit a consistent truncation where the only dynamical field is the metric and its equation of motion is Einstein's equation with a negative cosmological constant. All solutions of this equation which are asymptotically AdS, would describe the states (and their time-evolution) in the universal sector of the dual gauge theories. Since these solutions would exist in any supergravity theory, the states (and their time evolution) they describe would exist in any conformal gauge theory and hence they comprise the universal sector. In collaboration with Rajesh Gupta, I have shown that all of these solutions are uniquely characterised by the boundary stress tensor alone when the boundary metric is flat. This would imply that the states in the universal sector of the conformal gauge theories are uniquely characterised by the vev of the stress tensor when the gauge theory lives in flat space. We have further shown that in the Fefferman-Graham coordinates, in all these solutions (with flat boundary metric) the metric tensor has an even power series expansion in the radial coordinate. This in conjunction with an earlier result (for even dimensional spaces) indicate that whenever the conformal anomaly of the dual gauge theory vanishes, the solutions of supergravity with AdS asymptotics would admitt an even power series expansion in the radial coordinate in the Fefferman-Graham coordinate system. In particular we have demonstrated this for the solutions found by Shiraz Minwalla and his collaborators which describe the universal hydrodynamic sector of gauge theories. Currently, we are trying to find a general criterion which the boundary stress tensor should satisfy so that the supergravity solution is free of naked singularities. The motivation for this is that this would lead us to the complete identification of the universal sector of all conformal gauge theories in four dimensions with gravity duals, in which the stress tensor vev uniquely characterizes the state and its time evolution.

Preprints:

1. Justin R. David, Rajesh Gopakumar, Ayan Mukhopadhyay, *Worldsheet properties of extremal correlators in ADS/CFT*, to appear soon

Conference/Workshops Attended:

1. *Les Houches String School*, France, July, 2007

Invited Lectures/Seminars:

1. *Worldsheet properties of extremal correlators in ADS/CFT*, ISM 2007, HRI, HRI, October, 2007.

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Biswarup Mukhopadhyaya

Research Summary:

A detailed study of doubly charged scalars, such as those that can render neutrinos massive, has been carried out in the context of the LHC. Hitherto unexplored production mechanisms as well as novel detection channels have been suggested (with T. Han, Z. Si, K. Wang).

An elaborate investigation has been carried out on the effects of gaugino non-universality in supersymmetry (SUSY) and its impact on multichannel analyses at the LHC. Possible ways of distinguishing among various grand unified theories have been suggested (with Subhaditya Bhattacharya and Asesh K. Datta).

Some new signals have been suggested for a light Higgs boson in a CP-violating SUSY scenario. ways of getting over various contaminating agents for these signals have been suggested (with Priyotosh Bandyopadhyay, Amitava Datta and Asesh K. Datta)..

Some ways of distinguishing SUSY theories from Little Higgs scenarios with T-parity at the LHC have been suggested. It is shown in particular that trilepton events can be useful in this respect (with Asesh K. Datta, Paramita Dey, Sudhir K. Gupta and Andreas Nyffeler).

New features of theories with SU(2) triplet Higgs have been explored. In particular, it has been pointed out that the minimal version of such theories used in explaining neutrino masses have an inconsistency about them, which can be overcome only by augmenting the Lagrangian with terms that can alter observed phenomena substantially.

A study of bulk tensor fields of rank higher than two has been carried in the context of a Randall-Sundrum model. It has been shown that such higher rank fields, which can arise as modes of excitation of an open string, have progressively smaller coupling to matter fields in the 3-brane comprising the visible world, thus explaining why gravity plays the key role in the evolution of the universe (with Somasri Sen and Soumita SenGupta)..

Publications:

1. Tao Han, Biswarup Mukhopadhyaya, Zongguo Si and Kai Wang, *Pair production of doubly-charged scalars: Neutrino mass constraints and signals at the LHC,* Phys. Rev. **D76**, 075013 (2007)

2. Rathin Adhikari, Anindya Datta, Biswarup Mukhopadhya, *The Neutrino*

mass scale and the mixing angle theta(13) for quasi-degenerate Majorana neutrinos, Phys. Rev. **D76**,073003 (2007)

3. Subhaditya Bhattacharya, AseshKrishna Datta, Biswarup Mukhopadhya, *Non-universal gaugino masses: A Signal-based analysis for the Large Hadron Collider,* JHEP **0710**, 080 (2007)

4. AseshKrishna Datta, Paramita Dey, Sudhir Kumar Gupta, Biswarup Mukhopadhyaya, Andreas Nyffeler, *Distinguishing the Littlest Higgs model with T-parity from supersymmetry at the LHC using trileptons,,* Phys. Lett. **B659**, 308 (2008)

5. Biswarup Mukhopadhyaya, Somasri Sen, Soumitra SenGupta, *Bulk antisymmetric tensor fields in a Randall-Sundrum model,* Phys. Rev. **D76**, 121501 (2007)

Preprints:

1. Priyotosh Bandyopadhyay, Amitava Datta, Aseshkrishna Datta, Biswarup Mukhopadhya, *Associated Higgs production in CP-violating supersymmetry: Probing the 'open hole' at the large hadron collider,* arXiv:0710.3016 [hep-ph]

2. Paramita Dey, Anirban Kundu, Biswarup Mukhopadhyaya, *Some consequences of a Higgs triplet,* arXiv:0802.2510 [hep-ph]

Conference/Workshops Attended:

1. *Pheno-2008*, University of Wisconsin, Madison, USA, May, 2007.

2. *Preparing for the LHC*, KITP, University of California, Santa Barbara, USA, February-March, 2008.

3. *Higgs Hunters' Meeting*, Visva-Bharati, Santiniketan, February, 2008.

4. *Nu-Horizon*, Harish-Chandra Research Institute, February, 2008.

Visits to other Institutes:

1. University of Wisconsin, Maddison, USA, April-May, 2007.

2. Fermi National Accelerator Laboratory, USA, May, 2007.

3. University of California, Santa Barbara, USA, February-March, 2007.

4. University of Calcutta, December, 2007.

5. Indian Association for the Cultivation of Science, Kolkata, August, 2007.

Invited Lectures/Seminars:

1. *Right-handed neutrinos in a supersymmetric world*, Pheno-08, University of Wisconsin, Madison, May, 2007.
2. *Dogs that do not bark- supersymmetry and right-handed neutrinos*, University of Wisconsin, Madison, May, 2007.
3. *Dogs that do not bark- supersymmetry and right-handed neutrinos*, Fermilab Theory Seminar, Fermilab, May, 2007.
4. *Some consequence of right-handed neutrinos*, Shyamal Sengupta Memorial Lecture, Indian Association for the Cultivation of Science, Kolkata, August, 2007.
5. The LHC and elementary particles, Refresher programme for college teachers, University of Calcutta, September, 2007.
6. *Particle physics and the standard model (12 lectures)*, SERC Preparatory School, Banaras Hindu University, December, 2007.
7. The LHC experiment, One-day seminar on high energy physics, University of Calcutta, February, 2008.
8. Neutrinos and the LHC, Nu-Horizon, HRI, February, 2008.

Other Activities:

1. Acted as co-ordinator, Regional Centre for Accelerator-based Particle Physics, Harish-Chandra Research Institute.
2. Currently Dean (academic), Harish-Chandra Research Institute.

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Satchidananda Naik

Research Summary:

The Closed string field theory of self-dual $N = 8$ 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 closed string field theory to describe the self-dual $N = 8$ supergravity in a covariant fashion with the hope of getting MHV amplitudes for this theory.

Conference/Workshops Attended:

1. *International Conference on Non-Perturbative gauge theories and gravity* , India , January7-12 ,2008

Visits to other Institutes:

1. National Center for theoretical Physics,National Taiwan university, Taipei, Taiwan for September 2007

Invited Lectures/Seminars:

1. *N=8 Self-dual Supergravity as Closed string field theory in Twistor Space*, invited Lecture in Conference SN Bose center, Kolkata, January 2008.

2. *Closed String field theory for self-dual gravity in twistor space*, String theory Seminar, NTU, Taiwan, september 2007.

Courses Given:

1. Advanced Quantum Mechanics , 1st Jan-15th May, 2008.

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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.

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

Little Higgs models have been proposed as a solution to the hierarchy problem of the Standard Model. 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 (ILC). 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 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 or Universal Extra Dimensions with KK-parity. With my colleagues at HRI, I have started to work out some consequences for searches for these new particles in the Littlest Higgs model with T-parity at the LHC and how to distinguish the signals from the MSSM.

Distinguishing the Littlest Higgs model with T-parity from supersymmetry at the LHC using trileptons
(with AseshKrishna Datta, Paramita Dey, Sudhir Kumar Gupta and Biswarup Mukhopadhyaya)

We analyzed hadronically quiet trilepton signatures in the T-parity conserving Littlest Higgs model and in R-parity conserving supersymmetry at the Large Hadron Collider. We identified the regions of the parameter space where such signals can reveal the presence of these new physics models above the Standard Model background and distinguish them from each other, even in a situation when the mass spectrum of the Littlest Higgs model resembles the supersymmetric pattern.

II. Anomalous magnetic moment of the muon

I have been asked by Fred Jegerlehner (Humboldt University and DESY Zeuthen, Germany) to join him in writing a review article for Physics Reports on the anomalous magnetic moment of the muon. In addition to a summary of existing works on various contributions to the $g-2$ in the Standard Model and within a selection of New Physics models, we are currently reevaluating the hadronic light-

by-light scattering contribution. In particular, we want to correct some mistakes in the recent literature and develop a framework which reproduces the available experimental data and fulfills all theoretical constraints from QCD at long and short-distances. 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.

Publications:

1. R.S. Hundi, B. Mukhopadhyaya and A. Nyffeler, *Invisibly decaying Higgs boson in the Littlest Higgs model with T-parity,* AIP Conf. Proc. **939**, 59, (2007)

2. A.K. Datta, P. Dey, S.K. Gupta, B. Mukhopadhyaya and A. Nyffeler, *Distinguishing the Littlest Higgs model with T-parity from supersymmetry at the LHC using trileptons,* Phys. Lett. B **659**, 308, (2008)

Conference/Workshops Attended:

1. *School on QCD at LHC*, Allahabad, India, November 2007
   Lectures on: Dimensional regularization, $\overline{\rm MS}$ renormalization of QCD to one loop, beta function and asymptotic freedom, determinations of α_s

2. *Xth Workshop on High Energy Physics Phenomenology (WHEPP-X)*, Chennai, India, January 2008
   Talk: Little Higgs at the LHC

Visits to other Institutes:

1. ETH, Zürich, Switzerland, May 2007 (1 week)

2. Centre de Physique Théorique, Marseille, France, June 2007 (1 week)

3. University of Bern, Switzerland, June 2007 (2 weeks)

Invited Seminars:

1. *Little Higgs at the LHC*, ETH, Zürich, Switzerland, May 2007

2. *Little Higgs at the LHC*, CERN (CMS Higgs Working Group), Geneva, Switzerland, May 2007

3. *Little Higgs at the LHC*, Centre de Physique Théorique, Marseille, France, June 2007

4. *Little Higgs at the LHC*, University of Bern, Switzerland, June 2007

Other Activities:

1. Pheno lunch talk: Narrow width approximation limitations and Breakdown of the Narrow Width Approximation for New Physics (based on hep-ph/0703077 and hep-ph/0703058), April 2007.

2. I was involved in the organization of and lecturing at a school on "QCD at LHC", held at HRI in November 2007.

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Sudhakar Panda

Research Summary:

The effective action for gravitational interaction resulting from string theory contains, besides the usual two derivative terms, many higher derivative terms. The entropy of the black holes in this theory, thus, gets contributions from these higher derivative terms as well. A class of these black holes are found to have the same entropy as expected from supersymmetric black holes. This observation requires that the effective action itself should be supersymmetric. Since the effective actions are constructed in a way which does not guarantee manifest supersymmetry, one has to explicitly construct supersymmetric actions involving the higher derivative terms. We showed that the supersymmetric R^2 effective action for the heterotic string theory, obtained from the supersymmetrization of the Lorentz Chern-Simons term, is to alpha-prime order, equivalent modulo field redefinition to heterotic string effective actions computed by sigma model approach. This clarifies the reason for matching of black hole entropy computed for the extremal black hole.

We studied D-brane inflation in a warped conifold background that includes brane position dependent corrections to the non-perturbative superpotential. This corrections lead to an interacting theory of volume modulus and the scalar field corresponding to the position of the D-brane (radion). In this scenario, stabilization of the volume modulus ammounts to giving it an expectation value in one of the instantaneous minima and treating the radion as the inflaton. However, this not lead to a viable inflationary model. On the other hand, if we consider the inflationary model to be a two fields model, the dynamics itself can stabilize the volume modulus and we can have a reasonable model. This has been studied in details.

We are studying the thermodynamics of a black hole associated with Born-Infeld system with dilaton and axion fields coupled to gravity.

The origin of a tachyonic instability in the motion of a D-brane in the background of a stack of NS5-brane is being investigated.

Publications:

1. Sudhakar Panda, *A Brief Survey of Strings/Brane Cosmology* **PoS** (stringsLHC) 021 (2007)

2. M.de Roo, W.A.Chemissany and Sudhakar Panda, α' - *Corrections to Heterotic Superstring Effective Actions Revisited,* JHEP **08**, 037, (2007)

3. Sudhakar Panda, M.Sami and S.Tsujikawa, *Prospects of inflation in delicate D-brane cosmology,* Phys. Rev. **D 78**, 103512, (2007)

Preprints:

1. M.de Roo, W.A. Chemissany and Sudhakar Panda, *α'-corrections to Heterotic Superstring Effective actions Revisited,* arXiv:0706.3636 [hep-th]

2. Sudhakar Panda, M.Sami and S. Tsujikawa, *Prospects of inflation in delicate D-brane cosmology,* arXiv:0707.2848 [hep-th]

Conference/Workshops Attended:

1. *INSM-07 (Indian National String meeting)*, Allahabad, India, 2007.

2. *FTAG-VI (Field theoretic aspects of gravity)*, Allahabad, India, 2007.

3. *From Strings to LHC, Bangalore*, India, 2007.

4. *ICGC-07 (International Conference on Gravitation and Cosmology)*, IUCAA, Pune, India, 2007.

Visits to other Institutes:

1. Ngoya University, Nagoya, Japan, 2007.

2. Gunma National College of Technology, Gunma, Japam, 2007.

3. Centre for Theoretical Physics, Univ. of Groningen, Groningen, The Netherlands, 2007.

4. IMSC, Chenai, India, 2007.

5. University of Rochester, NY, USA, 2008.

Invited Lectures/Seminars:

1. *Searching for Unified Theory*, Colloquium at Nagoya University, Nagoya, Japan, 2007.

2. *Elementary paticles and their Interactions*, interactive discussion with students at Gunma National College of Technology, Japan, 2007.

3. *Can Inflation stabilize the volume modulus in String theory?* University of Groningen, The Netherlands, 2007.

4. *Moduli stabilization and Brane Inflation*, Invited talk, FTAG-VI, 2007.

5. *Moduli stabilization and Brane Inflation*, Invited talk, INSM 2007.

6. *Moduli stabilization and Brane Inflation*, Invited talk, From Strings to LHC, Bangalore, 2007.

7. *Moduli stabilization and Brane-antiBrane Inflation*, IMSC, Chenai,2007.

Other Activities:

1. Member,Local Works Committee, 2007-08.

2. Member, Library Committee, 2007-08.

3. Member, Board of Studies, CTP, Jamia-Milia Univ, Delhi.

4. External Member, Ph.D defence board, Groningen university, 2007.

5. Thesis and external examiner, TIFR graduate student, 2007.

6. Chairman, Quantum Gravity part of ICGC, Pune, 2007.

7. Taught a course on Quantum Field Theory under HRI Ph.D. course program, January-May 2007.

8. Supervised one student under the visiting students research program of HRI, Oct-Nov 2007.

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Tribhuvan Prasad Pareek

Research Summary:

I have been involved in studying spin physics in low dimensional systems.Over the past few years the considerable developments in spin transport phenomena in mesoscopic and macroscopic systems have taken place. In spite of these advances spin currents and its consequence for transport still remain poorly understood. Over last few years we have been involved in developing a conceptual framework using spin density matrix scattering theory to study and understand the spin currents and its effects on transport. We have made some important studies where it has been pointed out that in hybrid systems spin currents are defined properly in the leads and one does not need to worry about the continuity equation. Moreover, it has been conclusively shown that different **Magnetoresistance phenomena like - TMR, AMR etc.** are a consequence of spin currents. Thus the concept of spin currents provide novel way to understand magnetoresistance phenomena which occurs in large class of condensed matter systems.
Furthermore we have develop a non-equilibrium Green function methods applicable to multi-terminal systems to study spin transport at meso/nano scale where effects of leads and inelastic scattering have been taken into account. This is powerful since it allows us to study effects of inelastic scattering. Using this we have studies equilibrium spin currents and conclusively prove its existence in two terminal systems as well and bring to an end the controversies arising within Landauer Büttikerr approach.

Publications:

1. T. P. Pareek and A. M. Jayannavar, *Generation and measurement of nonequilibrium spin currents in two-terminal systems,* Phys. Rev. B. **77**, 153307, (2008)

2. T. P. Pareek, *spin transport in nanosystems,* SSP **52**, 12, (2007)

Preprints:

1. T. P. Pareek, *Equilibrium Spin Currents and its Measurement: An NEGF model* , (in preparation)

Conference/Workshops Attended:

1. *Workshop on Quantum Correlation and Quantum computation*, IIT Kharagpur, December 2007.

2. *DAE Solid State Symposium*, Mysore,India, December 2007.

3. *School on Low dimensional nanoscopic systems*, HRI Allahabad, Jan-Feb 2008.

4. *International School and conference on Quantum computation*, Bhubaneswar India, March 2008.

Visits to other Institutes:

1. Institute of Physics, Bhubaneswar, India, July 2007.

Invited Lectures/Seminars:

1. *Spintronics to Quantum computation*, QCQC-2007, IIT Kharagpur, Kharagpur, December 2007.

2. *Spintransport in Nanosystems*, 52 DAE SSP, University of Mysore, Mysore, December 2007. *Spintronics*, School on Low dimensional nanoscopic systems , HRI, Allahabad, Jan-Feb 2008.

3. *Quantum computation in solid state systems*, ISCQI- 2008, Institute of Physics, Bhubaneswar, March 2008.

Other Activities:

1. Beside the academic responsibilities I contribute in administrative matters by being a member of administrative committees. I have guided 3 VSP students during last year.

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Kalpataru Pradhan

Research Summary:

1. Disorder on the active d element site(B site of ABO_3) is usually very disruptive for conduction and long range order in perovskite transition metal oxides. However, in the background of phase competition such 'B site' dopants also act to promote one ordered phase at the expense of another. This occurs either through valence change of the transition metal or via creation of 'defects' in the parent magnetic state. We provide a framework for understanding the complex variety of phenomena observed in B site doped manganites and identify the key parameters that control the physics. We study a two orbital double-exchange model in two dimensions in the presence of anti-ferromagnetic superexchange, Jahn-Teller Coupling and substitutional disorder. Using a spatially resolved analysis of B ions in various manganite phases we explain the existing data and predict new situations where highly polarisable phase separated states can be created. In addition to the detailed numerical results we are able to identify the hierarchy of physical effects that control the impact of B dopants on the manganites.

2. The melting of charge order in the half-doped manganites with unexpected small external magnetic field, dramatic impact of disorder in magnetic field, and unusual hysteresis in the field response presents few puzzles in correlated electron systems. We study magnetic field effects in a disordered strong coupling model appropriate to the manganites and show that these attributes arises naturally from the proximity of several phases in the Landau free energy landscape and spatially inhomogeneity introduced by structural disorder.

3. We studied the geometry, electronic structure and spin multiplicity of Sc, Ti and V doped Na_n (n = 4, 5, 6) clusters within a gradient corrected density functional approach. Two complementary approaches including all-electron calculations on free clusters, and supercell calculations using plane wave pseudopotential and projector augmented wave formalisms have been carried out. It is shown that spin magnetic moments of the transition metal atoms, the magnitude of host polarization, and the sign of the host polarization all change with the number of alkali atoms. In particular the transition metal(TM) atoms are shown to attain spin moments that are higher than their atomic values. The role of hybridization between the transition atom d-states and the alkali sp-states is highlighted to account for the evolutions

in the spin moments and host polarization. We also extended our work to Cr, Mn, Fe, Co, Ni doped Na clusters for n=4, 5, 6 ,7. Due to little or no spd hybridization (because most of the late $3d$ TM atoms have more localized d orbitals compared to the early $3d$ TM) transition metals retain their magnetic moments for even number of Na atoms and 1 unit less for odd Na atoms.

Publications:

1. Kalpataru Pradhan, Anamitra Mukherjee and Pinaki Majumdar, *The distinct Effect of Homogeneous Weak Disorder and Dilute Strong Scatterers on Phase Competition in the manganites,* Phys. Rev. Lett., **99**, 147206, (2007)

2. Kalpataru Pradhan, Prasenjit Sen, J. U. Reveles , S. N. Khanna, *First principles study of Sc, Ti and V doped Na_n(n =4, 5, 6) clusters: Enhanced magnetic moment,* Phys. Rev. B, **77**, 045408, (2008)

Preprints:

1. Kalpataru Pradhan, Prasenjit Sen, J. U. Reveles , S. N. Khanna, *First-principles study of $TMNa_n$(TM= Cr, Mn, Fe, Co, Ni; n = 4-7) clusters,* arXiv:0804.0361

2. Kalpataru Pradhan, Anamitra Mukherjee and Pinaki Majumdar, *Hysteresis and Inhomogeneous Melting in the Field Response of Half Doped Charge Ordered Manganites,* arXiv:0801.2054

3. Kalpataru Pradhan, Anamitra Mukherjee and Pinaki Majumdar, *Exploiting B Site Disorder for Electronic Phase Control in the Manganites,* arXiv:0710.2278

Conference/Workshops Attended:

1. *School on Low Dimensional Nanoscopic Systems*, HRI, Allahabad, India, 28th Jan-9th Feb, 2008.

2. *Correlated Electrons and Frustrated Magnetism*, Goa, India, 25th Nov-5th Dec, 2007.

Other Activities:

1. Condensed Matter talk on *Two distinct effects of disorder on a complex insulating state*

2. Condensed Matter talk on *Interfaces in oxides (fundamental science and technological application)*

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Sumathi Rao

Research Summary:

We continued our investigations of junctions of quantum wires. This year we concentrated on studying the effect of superconducting junctions, with new phenomena like Andreev reflection and crossed Andreev reflection in the wires, due to the proximity of the superconductor. Our aim was to study the effect of electron-electron interactions on such systems. We used the weak interaction renormalisation group method to look for new fixed points in such a system.

We are also studying junctions of single-channel spinless Luttinger liquids using bosonisation. We generalise earlier studies by allowing the junction to be superconducting and find new charge non-conserving low energy fixed points which are 'dual' to the normal charge conserving fixed points.

We are studying transport through a quantum wire connected to a stub coupled to a superconducting reservoir. In contrast to the standard stub geometry, here we find resonances not at $T = 1$, but at $T = 1/4$, which turns out to be an unstable fixed point.

We are studying the effect of electron-electron correlations on the noise at the junction of multiple quantum wires.

We are studying line junctions of $\nu = 1/2$ edges to see how the effect of co- and counter-propagating modes affect the fixed points of the system and consequently their stabilities.

Finally, we have started working on graphene and in particular, superconducting junctions in graphene.

Publications:

1. Sourin Das, Sumathi Rao and Arijit Saha, *Spintronics with NSN junction of one-dimensional quantum wires : a study of pure spin current and magentoresistance*, Europhys. Lett **81** 67001, (2008).

2. Sourin Das, Sumathi Rao and Arijit Saha, *Renormalisation group study of transport through a superconducting junction of one-dimensional quantum wires* Phys. Rev **B77**, 155418, (2008).

Preprints:

1. Sourin Das and Sumathi Rao, *Duality between charge conserving and charge non-conserving sectors of junctions of multiple quantum wires* (in preparation).

2. Sourin Das, Sumathi Rao and Arijit Saha, *Resonant transmission through a stub connected to a superconductor* (in preparation).

3. Sourin Das, Sumathi Rao and Arijit Saha, *Noise at the junction of multiple quantum wires* (in preparation).

4. Sourin Das, Sumathi Rao and Diptiman Sen, *Line junctions of $\nu = 5/2$ edge states* (in preparation).

Conference/Workshops Attended:

1. *Working group meeting of women in physics*, Phyzikscentrum, Bad Honnef, Germany, April 19-21, 2007.

2. *10th Asia Pacific Physics Conference*, Pohang, Korea, August 21-24, 2007.

3. *Correlated electrons and frustrated magnetism*, International Centre, Dona Paula, Goa, India, Dec 4-6, 2007.

4. *Quantum Correlations and quantum computing*, Indian Institute of Technology, Kharagpur, India, Dec 11-13 2007.

Visits to other Institutes:

1. Indian Institute of Science, Bangalore, India, December 2007.

Invited Lectures/Seminars:

1. *Progress report of women in Physics in India*. Bad Honnef, Germany, April, 2007.

2. *Junctions of quantum wires*, International Centre, Dona Paula, Goa, Dec 4, 2007.

3. *Spintronics with NSN junction of quantum wires*, Indian Institute of Technology, Kharagpur, Dec 11, 2007.

4. *Spintronics with NSN junction of quantum wires*, Indian Institute of Science, Bangalore, Dec 18, 2007.

Other Activities:

1. Organised an International School on '*Low dimensional nanoscopic systems*, Harish-chandra Research Institute, Allahabad, India, Jan 28-Feb 9, 2008.

2. Taught *quantum field theory I* , Jan-May 2008.

3. Convenor, Local works committee.

4. Convenor, Women's grievance cell.

5. Member, Faculty Advisory committee and Budget committee.

6. Member, Working group of women in physics, International Union of Pure and Applied Physics.

7. Member, Board of Studies, School of Physics, Jawaharlal Nehru University, New Delhi.

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V. Ravindran

Research Summary:

Perturbative Quantum Chromodynamics (QCD) provides a framework to successfully compute various important observables in the hadronic colliders. Recent progresses in the computation of higher order QCD corrections have lead to predictions with unprecendented accuracy for physics studies at the Tevatron collider in Fermilab as well as at the upcoming Large Hadron Collider (LHC). The precise measurements of Z and W provide stringent tests of the standard model (SM), valuable information on the mass of the Higgs and also constrain various parameters of physics beyond the SM. In ref [1], we have studied the threshold enhanced perturbative QCD corrections to rapidity distributions of Z and $W^{\pm}$ bosons at hadron colliders using the Sudakov resummed cross sections at N^{3}LO level. We have used renormalisation group invariance and the mass factorisation theorem that these hard scattering cross sections satisfy to construct the QCD amplitudes. We show that these higher order threshold QCD corrections stabilise the theoretical predictions for vector boson production at the LHC under variations of both renormalisation and factorisation scales.
The scale invariant "unparticle physics" proposed by Georgi could manifest at low energies as non integral number d_U of invisible particles. These are called unparticles. They could couple to the Standard Model fields and consequently affect the collider phenomenology. We have studied [2] the Drell-Yan process at hadronic colliders to explore effects of the peculiar propagator of the scalar and tensor unparticle operators. To probe these effects at hadron collider one needs to go beyond LO in QCD and hence the quantitative impact of QCD corrections for unparticle physics at LHC is investigated. We present the K-factors at LHC. Inclusion of QCD corrections to NLO stabilises the cross section with respect to scale variations. We have also investigated [3] the effects coming from these unparticles to diphoton signals at the hadron colliders. We have shown that the unparticle signals can be seen in certain parameter space of the model in the invariant mass and other kinematical distributions of the diphoton system.

Publications:

1. V. Ravindran and J. Smith,*Threshold corrections to rapidity distributions of Z and $W^{\pm}$ bosons beyond N^2LO at hadron colliders,* Phys. Rev. D **76**, 114004 (2007), [arXiv:0708.1689 [hep-ph]].

2. P. Mathews and V. Ravindran, *Unparticle physics at hadron collider via dilepton production,* Phys. Lett. B **657**, 198, (2007), [arXiv:0705.4599 [hep-ph]].

3. M. C. Kumar, P. Mathews, V. Ravindran and A. Tripathi,*Unparticle physics*

in diphoton production at the CERN LHC, Phys.Rev. **D77**, 055013,(2008) arXiv:0709.2478 [hep-ph].

Preprints:

1. P. Mathews and V. Ravindran, QCD prerequisites for extra dimension searches, arXiv:0707.4080 [hep-ph].

Conference/Workshops Attended:

1. *From Strings to LHC - II*, Fireflies Ashram, Bangalore, December 19-23, India.
2. *Workshop on High Energy Physics Phenomenlogy*, Institute of Mathematical Sciences, Chennai, January 2-11, 2008.
3. *CTS workshop on Physics of warped extra dimensions*, Indian Institute of Technology, Kharagpur, India, February 21-23, 2008.
4. *Higgs Hunters' Meeting 2008*, Visva-Bharati University, Santiniketan, India, February 7-9, 2008.
5. *HEPCOS-2008*, Centre for Theoretical Physics, Jamia Millia Islamia, March 11-12 , 2008.
6. *Modern developments in SUSY breaking, Extra Dimensional theories and unparticles*, Center for High Energy Physics, March 25-29, 2008.

Visits to other Institutes:

1. Lorentz Institute, University of Leiden, Leiden, The Netherlands, June to August 2007.
2. NIKHEF, Amsterdam, The Netherlands, June 22, 2007.
3. Centre de Physique Theorique, Ecole Polytechnique, Paris, July,16-20, 2007.
4. Universitat Wuppertal, Wuppertal, Germany, August 7-8, 2007.
5. Rheinisch-Westfaelische Technische Hochschule Aachen, Aachen, Germany, August 15-17, 2007.

Invited Lectures/Seminars:

1. *Sudakov resummation and theshold effects in Drell-Yan and Higgs productions*, Theory Seminar, Centre de Physique Theorique, Ecole Polytechnique, Paris, July, 2007.

2. *QCD Threshold effects in Drell-Yan and Higgs productions*,Theory Seminar, Universitat Wuppertal, Wuppertal, Germany, August 7, 2007.

3. *QCD threshold effects to Drell-Yan and Higgs productions*,Theory Seminar, Rheinisch-Westfaelische Technische Hochschule Aachen, Aachen, Germany, August 16, 2007.

4. *Soft gluon contributions to Drell-Yan and Higgs Productions beyond NNLO*, 8th International Symposium on Radiative Corrections, APPLICATION OF QUANTUM FIELD THEORY TO PHENOMENOLOGY Florence, Italy, October 1-5, 2007.

5. *Three loop soft gluon corrections to di-lepton and Higgs productions at the LHC*, From Strings to LHC - II, Fireflies Ashram, Bangalore, December 19-23, India.

6. *Phenomenology of warped extra dimensions at LHC* , CTS workshop on Physics of warped extra dimensions, Indian Institute of Technology, Kharagpur, February, 2008.

7. *Soft gluon corrections to Higgs production at three loops in QCD*, Higgs Hunters' Meeting 2008, Visva-Bharati University, Santiniketan, February 7-9, 2008.

8. *Higgs production at LHC*, HEPCOS-2008 at Centre for Theoretical Physics, Jamia Millia Islamia, March 11-12 , 2008.

Other Activities:

1. Taught a course on Atomic, Molecular and Nuclear Physics for HRI graduate students.

2. Organised a school on "QCD at LHC" at Harish-Chandra Research Institute, November 25-30, 2007.

3. Given a set of lectures in school on "QCD at LHC" at Harish-Chandra Research Institute, November 25-30, 2007.

4. Guided three second-year Ph.D students for their projects.

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Amitava Raychaudhuri

Research Summary:

In 2007-08, research has been carried out in aspects of neutrino physics, particle physics models based on space-time with extra dimensions, and quark models.

In continuing work on the prospects of the proposed Iron Calorimeter detector at INO being used as an end-detector for a very long baseline experiment in conjunction with a beta-beam source in Europe, it has been shown that this set-up has unmatched sensitivity for probing many of the remaining unknowns of the neutrino mass matrix. Related work on long baseline experiments with a beta-beam have (a) explored the possibility of using the survival probability P_{ee} and (b) optimised the baseline, boost-factor, and luminosities for the best reach for probing the open issues of neutrino physics.

The upper bound on the mass of the lightest neutral higgs scalar is shown to be considerably relaxed in models in which SUSY is embedded in space-time of more than four dimensions.

Even though the observational evidence for the 'pentaquark' is currently not strong, such a bound state is a consequence of QCD. The group theory of the 'triquark' – which is a aconstitutent of the pentaquark – has been examined with a focus on the colour-spin SU(6) structure. Using these results, the masses of the different pentaquak states and their colour-spin excitations have been estimated.

Publications:

1. Sanjib Kumar Agarwalla, Sandhya Choubey, Srubabati Goswami, and Amitava Raychaudhuri, *Neutrino parameters from matter effects in P_{ee} at long baselines,* Phys. Rev. **D75,** 097302 (2007)

2. Abhijit Samanta, Sudeb Bhattacharya, Ambar Ghosal, Kamales Kar, Debasish Majumdar, and Amitava Raychaudhuri, *A GEANT-based study of atmospheric neutrino oscillation parameters at INO,* Int. J. Mod. Phys. **A23,** 233-245 (2008)

3. Gautam Bhattacharyya, Swarup Kumar Majee, and Amitava Raychaudhuri, *Extra-dimensional relaxation of the upper limit of the lightest supersymmetric neutral Higgs mass,* Nucl. Phys. **B793,** 114-130 (2008)

Preprints:

1. S. K. Agarwalla, S. Choubey and A. Raychaudhuri, *Magic Baseline Beta Beam,* AIP Conf. Proc. **939**, 265 (2007) arXiv:0707.3367 [hep-ph]

2. Sanjib Kumar Agarwalla, Sandhya Choubey and Amitava Raychaudhuri, *Unraveling neutrino parameters with a magical beta-beam experiment at INO,* arXiv:0711.1459 [hep-ph] Nucl. Phys. B (to appear)

3. Swarup Kumar Majee and Amitava Raychaudhuri, *SU(6), Triquark states, and the Pentaquark,* arXiv:0711.3910 [hep-ph] Phys. Rev. (to appear)

4. S. K. Agarwalla, S. Choubey and A. Raychaudhuri, *Physics with Beta-Beam,* AIP Conf. Proc. **981**, 84 (2008) arXiv:0712.4072 [hep-ph]

5. S. K. Agarwalla, S. Choubey, A. Raychaudhuri and W. Winter, *Optimizing the greenfield Beta-beam,* arXiv:0802.3621 [hep-ex]

Conference/Workshops Attended:

1. *HEPCOS 2008*, Jamia Millia Islamia, New Delhi, March, 2008.

2. *Higgs Hunters' Meeting*, Visva-Bharati, Santiniketan, February, 2008.

3. *Theophys-2007*, ISI, Kolkata, December, 2007.

4. *KEK-INO Meeting*, KEK, Japan, November, 2007.

5. *Indian Academy of Sciences Mid-Year Meeting*, Bangalore, July, 2007.

6. *BCSPIN 2007*, GUCAS, Beijing, China, June, 2007.

7. *Workshop on Possible Partiy Restoration at High Energies*, IHEP, Beijing, China, June, 2007.

Visits to other Institutes:

1. Center for High Energy Physics, Peking University, Beijing, China, June, 2007.

Invited Lectures/Seminars:

1. *Neutrino physics and INO*, HEPCOS 2008, Center for Theoretical Physics, Jamia Millia Islamia, New Delhi, March, 2008.

2. *Extra-dimensional limits on the Higgs mass from vacuum stability and triviality*, Higgs Hunters' Meeting, Visva-Bharati, Santiniketan, February, 2008.

3. *Nuances of Neutrinos*, Theophys-2007, ISI, Kolkata, December, 2007.

4. *Physics with INO*, KEK-INO Meeting, KEK, Japan, November, 2007.

5. *Nuances of Neutrinos*, Refresher Course in Physics, University of Calcutta, September, 2007.

6. *Let's talk about INO*, Indian Academy of Sciences Mid-Year Meeting, Bangalore, July, 2007.

7. *The India-based Neutrino Observatory: Status and Physics Prospects*, BCSPIN 2007, Beijing, China, June, 2007.

8. *Relaxing the lightest SUSY higgs mass via extra-dimensions*, Kavli Institute, Beijing, China, June, 2007.

9. *Extra-dimensional relaxation of the mass limit of the lightest neutral SUSY higgs*, Centre for High Energy Physics, Peking University, Beijing, China, June, 2007.

10. *Low intermediate scales in SUSY SO(10) GUTs with left-right symmetry*, Workshop on Possible Parity Restortion at High Energies, IHEP, Beijing, China, June, 2007.

11. *The Particle Play*, KVPY Summer Programme, HRI, Allahabad, May, 2007.

12. *Modeling the Building Blocks of the Universe*, Mathematical Modeling and its Engineering Applications, B.P. Poddar Institute of Management and Technology, Kolkata, April, 2007.

Other Activities:

1. Member, Physical Sciences Subject Expert Committee for the FIST Programme, Department of Science and Technology, Govt. of India.

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Arijit Saha

Research Summary:

For the last one year I am working on the the effect of **electron electron** (e-e) interaction on transport through a superconductor at the junction of multiple one-dimensional quantum wires and analyze some of the applications and utilities of such junctions.

We demonstrate possible scenarios for production of pure spin current and large tunnelling magnetoresistance ratios from **elastic co-tunnelling** and **crossed Andreev reflection** across a superconducting junction comprising of normal metal-superconductor-normal metal (NSN), where, the normal metal is a one-dimensional interacting quantum wire (**Luttinger liquid**). We show that there are fixed points in the theory which correspond to the case of **pure spin current**. We analyze the influence of electron-electron interaction and see how it stabilizes or de-stabilizes the production of pure spin current. These **fixed points** can be of direct experimental relevance for **spintronics** application of normal metal-superconductor-normal metal junctions of one-dimensional quantum wires. We also calculate the power law temperature dependence of the *crossed Andreev reflection enhanced* **tunnelling magnetoresistance** ratio for the ferromagnet- superconductor-ferromagnet (FSF) junction. We show that the tunnelling magnetoresistance has a high value (**magnitude of 2**) compared to ferromagnet- normal metal- ferromagnet (FNF) junction which can have significant importance in device application.

We investigate transport properties of a superconducting junction of many ($N \geq 2$) one-dimensional quantum wires (**Luttinger liquid**). We include the effect of electron-electron interaction within the one-dimensional quantum wires using a weak interaction renormalization group (**WIRG**) procedure. In the presence of a superconductor, superconductivity is being induced inside the quantum wires by **proximity effect**. Due to the proximity effect, transport across the junction occurs via direct tunneling as well as via the crossed Andreev channel. We find that the fixed point structure of this system is far more rich than the fixed point structure of a normal metal$-$superconductor junction ($N = 1$), where we only have two fixed points - the fully insulating fixed point ($r = 1$) which is stable under RG or the Andreev fixed point ($r_A = 1$) which is unstable under RG. Even a two wire ($N = 2$) system with a superconducting junction ie a normal metal$-$superconductor$-$normal metal structure, has non-trivial fixed points with intermediate transmissions and reflections ($r = 1/2$, $r_A = -1/2$, $t = 1/2$, $t_A = 1/2$). We also include electron-electron interaction induced back-scattering in the quantum wires in our study and hence obtain non-Luttinger liquid be-

haviour. It is interesting to note that *(a)* effects due to inclusion of electron-electron interaction induced back-scattering in the wire, and *(b)* competition between the charge transport via the electron and hole channels across the junction, give rise to a non-monotonic behavior of conductance as a function of temperature. We also find that transport across the junction depends on two independent interaction parameters. The first one is due to the usual correlations coming from the scattering of electron from Friedel oscillations for spin-full electrons giving rise to the well-known interaction parameter ($\alpha = (g_2 - 2g_1)/2\pi\hbar v_F$). The second one arises due to the scattering of electron into holes induced by the proximity of the superconductor and is given by ($\alpha' = (g_2 + g_1)/2\pi\hbar v_F$). The non-monotonic conductance and the identification of this new interaction parameter are two of our main results. In both the expressions $g_1 = V(2k_F)$, $g_2 = V(0)$, where $V(k)$ is the inter electron interaction potential.

We consider quantum charge pumping of electrons across a superconducting double barrier structure in the adiabatic limit. The superconducting barriers are assumed to be reflection-less so that an incident electron on the barrier can either tunnel through it or Andreev reflect from it. In this structure, quantum charge pumping can be achieved *(a)* by modulating the amplitudes, Δ_1 and Δ_2, of the gaps associated with the two superconductors or alternatively, *(b)* by a periodic modulation of the order parameter phases, ϕ_1 and ϕ_2 of the superconducting barriers. In the former case, we show that the superconducting gap gives rise to a very sharp resonance in the transmission resulting in quantization of pumped charge, when the pumping contour encloses the resonance. On the other hand, we find that quantization is hard to achieve in the latter case. We show that inclusion of weak electron-electron interaction in the quantum wire leads to renormalisation group evolution of the transmission amplitude towards the perfectly transmitting limit due to interplay of electron-electron interaction and proximity effects in the wire. Hence as we approach the zero temperature limit, due to renormalisation group flow of transmission amplitude we get destruction of quantized pumped charge. This is in sharp contrast to the case of charge pumping in a double barrier through a Luttinger liquid where quantized charge pumping is actually achieved in the zero temperature limit.

Publications:

1. Arijit Saha and Shamik Banerjee, Anamitra Mukherjee, Sumathi Rao, *Adiabatic charge pumping through a dot at the junction of N quantum wires,* Phys. Rev. B **75**, 153407, (2007)

2. Arijit Saha and Sourin Das, Sumathi Rao, *Spintronics with NSN Junction of one-dimensional quantum wires : A study of Pure Spin Current and Magnetoresistance,* Europhys.Lett. **81**, 67001, (2008)

3. Arijit Saha and Sourin Das, Sumathi Rao, *Renormalization group study of transport through a superconducting junction of multiple one-dimensional quantum wires,* Phys. Rev. B 77, 155418, (2008)

Preprints:

1. Arijit Saha and Sourin Das, *Quantized charge pumping in superconducting double barrier structure : Non-trivial correlations due to proximity effect,* e-Print: arXiv:0711.3216 [cond-mat]

Conference/Workshops Attended:

1. *Correlated Electrons and Frustrated Magnetism*, India (Goa), November 2007.
2. *Quantum Corellation and Quantum Computation*, India (IIT, Kharagpur), December, 2007.
3. *Low dimensional nanoscopic physics*, India (HRI, Allahabad), February, 2008.

Invited Lectures/Seminars/Posters:

1. *Poster presentation in the school on "Low dimensional nanoscopic physics":* Renormalization group study of charge and spin transport through a superconducting junction of multiple one-dimensional quantum wires, HRI, Allahabad, January 28 - February 9, 2008.

Other Activities:

1. Extension talk: *Zero-biased transport through a dot at the junction of multiple quantum wires*, April, 2007.
2. Journal club talk: *Electronic Correlations in Transport through Coupled Quantum Dots*, May, 2007.

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Bindusar Sahoo

Research Summary:

In the Current academic year I have worked on a couple of projects in different collaborations.

With Ashoke sen and Justin David we tried to look at the origin of the non-renormalizability of the entropy of BTZ black holes in supergravity. Earlier Krauss and Larsen used AdS/CFT correspondence to show that the entropy of BTZ black holes does not get renormalized to a certain order. We attributed it to the fact that AdS_3 supergravity prevents the addition of higher derivative terms apart from those which could be removed by field redefinition. Apriori this allows for a renormalization of the cosmological constant. However if the underlying conformal field theory in the boundary has appropriate supersymmetry then the cosmological constant gets related to the coefficient of a Chern-Simons term and hence is not renormalized . From this we argued that the entropy is completely fixed by the coefficient of the gauge as well as gravitational Chern-Simons terms as per Krauss and Larsen's non-renormalization theorem. It doesn't receive any further higher derivative corrections.

With Justin david we studied giant magnons in the the D1-D5 system from both the boundary CFT and as classical solutions of the string sigma model in $AdS_3 \times S^3 \times T^4$. Re-examining earlier studies of the symmetric product conformal field theory we argued that giant magnons in the symmetric product are BPS states in a centrally extended $SU(1|1) \times SU(1|1)$ superalgebra with two more additional central charges. The magnons carry these additional central charges locally but globally they vanish. Using a spin chain description of these magnons and the extended superalgebra we showed that these magnons obey a dispersion relation which is periodic in momentum. We then identified these states on the string theory side and showed that here too they are BPS in the same centrally extended algebra and obey the same dispersion relation which is periodic in momentum. This dispersion relation arises as the BPS condition for the extended algebra and is similar to that of magnons in $\mathcal{N} = 4$ Yang-Mills

Publications:

1. Justin R. David, Bindusar Sahoo, Ashoke Sen, *AdS_3, Black Holes and Higher Derivative Corrections*, JHEP **0707**, 058, (2007)

Preprints:

1. Justin R. David, Bindusar Sahoo, *Giant magnons in the D1-D5 system* , arXiv:0804.3267 (hep-th) (Submitted to JHEP)

Conference/Workshops Attended:

1. *Les Houches 2007 (Session LXXXVII) String Theory and the Real World From particle physics to astrophysics*, France, July 2007.
2. *Indian Strings meeting*, India, October 2007.
3. *The 2nd Asian Winter School on String Theory*, Japan, January 2008.

Visits to other Institutes:

1. Laboratoire de Physique Thorique et Hautes Energies (LPTHE), Paris, France, February 2008.
2. Universitat de Barcelona, Barcelona, Spain, February 2008.
3. Albert Einstein Institute, Potsdam, Germany, February 2008.
4. Indian Institute of Science, Bangalore, India, March 2008.

Invited Lectures/Seminars:

1. *Non-renormalization of the entropy of BTZ black holes*, Indian Strings meeting, HRI, Allahabad, October 2007.
2. *Non-renormalization of the entropy of BTZ black holes*, Institute Seminar, LPTHE, Paris, February 2008.
3. *Non-renormalization of the entropy of BTZ black holes*, Institute Seminar, Universitat de Barcelona, Barcelona, February 2008.
4. *Non-renormalization of the entropy of BTZ black holes*, Institute Seminar, Albert Einstein Institute, Potsdam, February 2008.
5. *Non-renormalization of the entropy of BTZ black holes*, Institute Seminar, Indian Institute of Science, Bangalore, February 2008.

Other Activities:

1. Gave a string theory Journal club talk on *Giant Magnons in the D1-D5 system*, April, 2008.
2. Tutored Quantum field theory course, 2007.
3. Gave a couple of lectures on *LSZ reduction* as a part of teaching assistanceship in the Quantum field theory course, 2007.

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Prabuddha Sanyal

Research Summary:

I have investigated the structural, magnetic and electronic properties of double perovskites $A_2BB'O_6$ in collaboration with Sabyasachi Tarat and Prof. Pinaki Majumdar. We studied the $B - B'$ ordering using the Ising model at constant magnetization, with the help of Monte Carlo methods. We also studied the domain growth as a function of annealing time and temperature. Thereby we explained the nonmonotonic behaviour of the degree of ordering observed experimentally as a function of annealing temperature. Secondly, I investigated the magnetic properties of an appropriate model for the double perovskites, using two different approaches. Firstly, I obtained an effective spin model for the clean problem with an exchange to be calculated self-consistently in the actual spin background. Assuming a ferromagnetic spin background, I explicitly calculated an analytic expression for this exchange, at T=0. Plugging this expression into the effective spin model, I did a Monte Carlo simulation, thereby obtaining an $N - T$ phase diagram, although only the $T = 0$ exchange has been used. Although the ferromagnetic phase was the starting point, we obtained antiferromagnetic phases with different ordering vectors, at intermediate values of filling.

In the second approach, we did an essentially exact calculation using Exact Diagonalization coupled with Monte Carlo (ED+MC), as also Travelling Cluster Approximation (TCA), from which we obtained the actual N_T phase diagram. Surprisingly, this phase diagram matches qualitatively (at least in the filling positions of all the different phases) with that obtained from the effective spin model, even though the latter started with the exchange evaluated in a non-self-consistent spin background. The T_c is however, overestimated in the effective spin model calculation, especially for some of the antiferromagnetic phases. We also obtained $\mu - N$ curves from the TCA calculation, which shows the jump discontinuities corresponding to first order phase transitions between the various phases. We also obtained explicit analytic expressions for the dispersions of each of the antiferromagnetic phases, and checked their relative stability in a variational sense, for different values of filling. This analysis bore out the relative filling positions of the different phases obtained from the ED+MC and TCA phase diagrams. hence, currently we can claim to have achieved a complete understanding of the clean problem. The next part of our project involves the tackling of the electronic-magnetic problem in presence of antisite disorder.

Publications:

1. P. Sanyal, S. Tarat and P. Majumdar, 'Studies on chemical ordering and an-

tisite defect formation in double perovskites', *cond-mat*,arXiv: 0804.1681.

2. P. Sanyal, S. Sen Gupta, N. Pakhira, H.R. Krishnamurthy, D.D. Sarma and T.V. Ramakrishnan, *Europhys. Lett.*, **82**, 47010 (2008).

Conference/Workshops Attended:

1. Conference on Correlated Electrons and Frustrated Magnetism (CEFM 07) held at International Center, Goa (December).

2. Indo-Japan conference on complex oxides and multiferroics held at the Indian Association for Cultivation of Science (IACS) Kolkata (February). Poster presented on 'Studies of structural ordering and magnetic properties of double perovskites'.

3. Conference on Nanoscopic systems held at HRI, Allahabad (January-February).

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Ashoke Sen

Research Summary:

My research during the period April 2007 - March 2008 focussed mainly on the study of black holes in string theory, both from macroscopic and microscopic perspective. On the macroscopic side I provided a way to understand the results for non-renormalization of the entropy of supersymmetric BTZ black holes by working directly on the gravity side (with David and Sahoo and with Gupta). On the microscopic side, I showed that the exact formula for the degeneracy of $N = 4$ supersymmetric dyons contains information about not only single centered black holes but also multi-centered black holes. I also showed that the degeneracy formula mentioned above is consistent with completely independent results based on the study of three string junctions. In collaboration with Shamik Banerjee I classified all the discrete duality invariants for heterotic string theory compactified on T^6. In collaboration with Shamik Banerjee and Yogesh Srivastava I found the formula for the dyon spectrum in heterotic string theory compactified on T^6 when the discrete duality invariants take non-trivial values. I also analyzed the dyon spectrum in type II string theory compactified on T^6 and derived the general wall crossing formula for dyons in $N = 4$ supersymmetric string theories from the study of multi-centered dyons in this theory.
Besides this I also worked on the subject of open string tachyon condensation and string field theory. In collaboration with Michael Kiermaier and Barton Zwiebach I developed the perturbation theory of open string field theory in a general class of gauges. In collaboration with Arjun Bagchi I studied tachyon condensation on a brane-antibrane system when the branes are initially separated by a distance.

Publications:

1. J. R. David, B. Sahoo and A. Sen, AdS_3, Black Holes and Higher Derivative Corrections,
   JHEP **0707**, 058 (2007) [arXiv:0705.0735 [hep-th]].
2. N. Banerjee, D. P. Jatkar and A. Sen, Adding charges to N = 4 dyons,
   JHEP **0707**, 024 (2007) [arXiv:0705.1433 [hep-th]].
3. A. Sen, Two Centered Black Holes and N=4 Dyon Spectrum,
   JHEP **0709**, 045 (2007) [arXiv:0705.3874 [hep-th]].
4. A. Sen, Rare Decay Modes of Quarter BPS Dyons,
   JHEP **0710**, 059 (2007) [arXiv:0707.1563 [hep-th]].

5. A. Sen, Three String Junction and N=4 Dyon Spectrum,
   JHEP **0712**, 019 (2007) [arXiv:0708.3715 [hep-th]].

6. R. K. Gupta and A. Sen, Consistent Truncation to Three Dimensional (Super-)gravity,
   JHEP **0803**, 015 (2008) [arXiv:0710.4177 [hep-th]].

7. S. Banerjee and A. Sen, Duality Orbits, Dyon Spectrum and Gauge Theory Limit of Heterotic String Theory on T^6,
   JHEP **0803**, 022 (2008) [arXiv:0712.0043 [hep-th]].

8. M. Kiermaier, A. Sen and B. Zwiebach, Linear b-Gauges for Open String Fields,
   JHEP **0803**, 050 (2008) [arXiv:0712.0627 [hep-th]].

9. S. Banerjee and A. Sen, S-duality Action on Discrete T-duality Invariants,
   JHEP **0804**, 012 (2008) [arXiv:0801.0149 [hep-th]].

10. A. Bagchi and A. Sen, Tachyon Condensation on Separated Brane-Antibrane System,
    JHEP **0805**, 010 (2008) [arXiv:0801.3498 [hep-th]].

11. S. Banerjee, A. Sen and Y. K. Srivastava, Generalities of Quarter BPS Dyon Partition Function and Dyons of Torsion Two,
    JHEP **0805**, 101 (2008) [arXiv:0802.0544 [hep-th]].

12. S. Banerjee, A. Sen and Y. K. Srivastava, Partition Functions of Torsion > 1 Dyons in Heterotic String Theory on T^6,
    JHEP **0805**, 098 (2008) [arXiv:0802.1556 [hep-th]].

Preprints

1. A. Sen, N=8 Dyon Partition Function and Walls of Marginal Stability,
   arXiv:0803.1014 [hep-th].

2. A. Sen, Wall Crossing Formula for N=4 Dyons: A Macroscopic Derivation,
   arXiv:0803.3857 [hep-th].

Invited Lectures/Seminars at Schools/Conferences:

1. Black hole entropy function and precision counting of mircostates, at Prestrings 2007, Granada, June 18-22, 2007.
2. Marginal Stability and N=4 Dyon Spectrum, at Strings 2007, Madrid, June 25-29, 2007.
3. Marginal Stability and N=4 Dyon Spectrum, at Eurostrings 2007, Crete, July 1-7, 2007.
4. N=4 dyons, at 30 Years of Mathematical Methods in High Energy Physics, March 17-19, 2008 RIMS, Kyoto, Japan.
5. Precision Counting of Black Hole Microstates, at Spring School On Superstring Theory And Related Topics, 27 Mar - 4 Apr 2008, Trieste, Italy.

Other Activities:

1. Taught Flux Compactification, January - May, 2007.
2. Taught General Relativity, August - December, 2007.
3. Taught Statistical Mechanics, January - May, 2008.

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Prasenjit Sen

Research Summary:

My main research effort during this period has been to understand electronic, magnetic and structural properties of transition metal (TM) doped small alkali metal clusters. I continued this work from the previous year, and gained thorough understanding of why Sc, Ti and V doped small sodium clusters show enhanced magnetic moments. This is due to large overlap of the TM $3d$ and Na sp atomic orbitals. Such enhancement of moments are found in clusters containing up to 9 Na atoms. Currently we are exploring larger sized clusters to understand how the magnetic moment evolves with increasing size. We have also studied Cr, Mn, Fe, Co and Ni doped Na_n clusters for $n = 4 - 7$. In these clusters, except for $NiNa_n$, the TM is bonded to the Na host through overlap of its $4s$ orbital with the sp orbitals of Na. There is essentially no overlap between the TM $3d$ and Na sp orbitals. This allows the TM atoms in these clusters to retain their atomic moments. A ferro- and anti-ferro magnetic coupling between the spin on the TM atom, and that on the Na host produces an odd-even oscillation in the magnetic moment with changing number of Na atoms. In $NiNa_n$ clusters, however, large spd mixing is observed. This leads to a complete quenching of the Ni moment in $NiNa_6$.

We proceeded with our idea of using a $Si_{60}H_{60}$ fullerene as a hydrogen storage material. The C_{60} fullerene, decorated from outside by TM atoms, has been explored for this purpose. It was claimed that each pentagonal or hexagonal face of C_{60} can bind one Ti atom, which can adsorb up to four H_2 molecules without dissociating them. The binding energy of the H_2 molecules to the Ti atom was also found to be within a range that make C_{60} based nanostructures practically attractive for hydrogen storage. However, it was later pointed out that Ti atoms do not remain isolated on different faces of a C_{60} fullerene, rather they prefer to cluster together. This seriously hinders their hydrogen storage capacity. We showed that such clustering tendency of Ti atoms is weaker on the face of a $Si_{60}H_{60}$ fullerene compared to a C_{60} fullerene. Moreover, replacing some of the Si atoms by P atoms leads to an enhancement of the binding energy of individual Ti atoms to the fullerene cage. This makes Ti clustering unfavorable. We, therefore, proposed that mixed Si-P based hydrogenated naostructures can be potential hydrogen media.

Publications:

1. K. Pradhan, P. Sen, J. U. Reveles, and S. N. Khanna, *First principles study of Sc, Ti and V doped Na_n ($n = 4, 5, 6$) clusters: Enhanced magnetic moments,* Phys.

Rev. B 77, 045408, (2008).

Preprints:

1. P. Sen, *On the question of ferromagnetism in alkali metal thin films,* arXiv:0711.4744.
2. K. Pradhan, P. Sen, J. U. Reveles, and S. N. Khanna, *First-principles study of $TMNa_n$ (TM= Cr, Mn, Fe, Co, Ni; $n = 4 - 7$) clusters,* arXiv:0804.0361.
3. S. Barman, P. Sen, and G. P. Das, *Ti decorated doped silicon fullerene: A possible hydrogen storage material,* (in preparation).
4. P. mahadevan and P. Sen, *Alkali metal oxides: An unusual class of magnetic materials,* (in preparation).

Conference/Workshops Attended:

1. *International Symposium on Theory of Atomic and Molecular Clusters*, USA, May 2007.
2. *10th International Conference on Advanced Materials*, India, October 2007.

Visits to other Institutes:

1. Indian Association for Cultivation of Science, Kolkata, India, July 2007.
2. Indian Institute of Technology, Kanpur, India, January 2008.

Invited Lectures/Seminars:

1. *Tuning magnetic properties of atomic clusters through size and composition*, Materials Science Seminar, Indian Association for the Cultivation of Science, Kolkata, July 2007.
2. *Tuning magnetic properties of atomic clusters through size and composition*, Physics Colloquium, IIT-Kanpur, Kanpur, January 2008.

Other Activities:

1. Organized a Summer School in Condensed Matter Physics in HRI, May-June 2007.
2. Taught a course on Numerical Methods, August-December, 2007.
3. Coordinated the activities of National Grid Initiative (Gadura) at HRI, throughout the year.

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Viveka Nand Singh

Research Summary:

We studied Mott transition in correlated fermionic system in infinite dimension using exact diagonalization approach. We calculated Green's function of infinite dimensional Hubbard model using an Anderson model with a finite number of sites. We have simulated this single site Anderson impurity problem with seven bath sites at half filling at $T = 0$ and we observed that when $U = 0$, we had metallic state. On increasing U, we found that quasiparticle weight starts decreasing at $\epsilon = 0$. And it disappears completely at critical value $U = 3.39$, Which is consistent with the result obtained by Caffarel and Krauth (PRL 1994). Also, the density of states was symmetric about $\epsilon = 0$, Which is indicative of particle-hole symmetry of the problem. In order to explain high Tc d-wave superconductivity etc of strongly correlated materials we have to use CDMFT, where we also have correlations within the cluster sites intact, while approximating longer-ranged physics on the mean field level. CDMFT is the natural generalization of DMFT, where the preffered sites is chosen as a cluster of n_c sites. The Green's function is chosen as a matrix within these sites. This method becomes exact when the cluster size diverges, and recovers corresponding mean field approximation when the cluster size become one. In CDMFT, we have been exploring the Lanczos based impurity solver. Then in order to attain large system sizes we applied Lanczos procedure to obtain ground states and few excited states in order to calculate Green's function. We have a working scheme for the ground state on systems upto $n_s = 12$ (matrix size=853776, 853776) and are working on calculation of spectral functions. When the Lanczos implementation is successful, we plan to study the quantum critical point and associated superconductivity in heavy fermions/ Kondo lattice models.

Conference/Workshops Attended:

1. *CEFM,TIFR*, India, December, 2008

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L. Sriramkumar

Research Summary:

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

- Deviations from slow roll inflation and features in the primordial spectrum
- Reheating and its effects on the evolution of perturbations

and the following issues in black hole physics:

- Sub-leading contributions to the black hole entropy
- Planck scale corrections to Hawking radiation

I have been studying the issues listed above under inflationary cosmology along with my graduate student Rajeev Kumar Jain. Brief description of the problems we have been considering in this context can be found in his report. In what follows, I shall outline two issues I have investigated in black hole physics.

Sub-leading contributions to the black hole entropy: In this work, we compute the canonical entropy of a quantum scalar field around static and spherically symmetric black holes through the brick wall approach at the higher orders (in fact, up to the sixth order in $\hbar$) in the WKB approximation. We explicitly show that the brick wall model generally predicts corrections to the Bekenstein-Hawking entropy in all spacetime dimensions. In four dimensions, we find that the corrections to the Bekenstein-Hawking entropy are of the form $(\mathcal{A}^n \log \mathcal{A})$, while, in six dimensions, the corrections behave as $(\mathcal{A}^m + \mathcal{A}^n \log \mathcal{A})$, where $\mathcal{A}$ denotes the area of the black hole event horizon and $(m, n) < 1$.

Planck scale corrections to Hawking radiation: Recently, it has been shown that, the T-duality symmetry of string fluctuations along compact extra dimensions leads to a modification of the standard propagator of point particles in quantum field theory. At low energies (when compared to the string scale), the modified propagator is found to behave as though the spacetime possesses a minimal length, which is assumed to be of the order of the Planck length. We utilize the duality approach to evaluate the modified propagator around the rotating Banados-Teitelboim-Zanelli black hole and show that the propagator is finite in the coincident limit. We compute the stress-energy tensor associated with the modified Green's function and illustrate that the quantum gravitational corrections turn out to be negligibly small.

Publications:

1. H. K. Jassal and L. Sriramkumar, *Entropy of BTZ black strings in the brick wall approach*, Classical and Quantum Gravity **24**, 2589 (2007).

2. R. K. Jain, P. Chingangbam and L. Sriramkumar, *On the evolution of tachyonic perturbations at super-Hubble scales*, Journal of Cosmology and Astroparticle Physics **10**, 003 (2007).

Preprints:

1. S. Sarkar, S. Shankaranarayanan and L. Sriramkumar, *Sub-leading contributions to the black hole entropy in the brick wall approach*, arXiv:0710.2013.

2. D. A. Kothawala, S. Shankaranarayanan and L. Sriramkumar, *Quantum gravitational corrections to the stress-energy tensor around the BTZ black hole*, arXiv:0801.0225.

Conferences/Workshops Attended:

1. *Himalayan Relativity Dialogue*, Mirik, April 18–20, 2007.

2. *The First Indo-Brazil Workshop on Cosmology*, Inter-University Centre for Astronomy and Astrophysics, Pune, July 16–21, 2007.

3. *Indian Conference on Cosmology and Galaxy Formation*, Harish-Chandra Research Institute, Allahabad, November 3–5, 2007.

4. *Field Theory Aspects of Gravity VI*, Harish-Chandra Research Institute, Allahabad, November 13–17, 2007.

5. *International Conference on Gravitation and Cosmology*, Inter-University Centre for Astronomy and Astrophysics, Pune, December 17–21, 2007.

6. *The Tenth Workshop in High Energy Physics Phenomenology*, Institute of Mathematical Sciences, Chennai, January 2–13, 2008.

7. *Prospects and Problems of Gravitation and Cosmology*, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, January 29–30, 2008.

Visits to other Institutes:

1. Korea Institute of Advanced Study, Seoul, Korea, April 29–May 15, 2007.

2. Chennai Mathematical Institute, Chennai, January 14–17, 2008.

3. Department of Physics, Indian Institute of Technology, Chennai, January 18, 2008.

4. Department of Physics and Astrophysics, University of Delhi, Delhi, January 21, 2008.

5. Inter-University Centre for Astronomy and Astrophysics, Pune, March 9–29, 2008.

Invited Lectures/Seminars:

1. *Quantum to classical transition of the primordial fluctuations*, Invited talk in Himalayan Relativity Dialogue, Mirik, April 18–20, 2007.

2. *The primordial spectrum as a probe of Planck scale physics*, Seminars at Korea Institute of Advanced Study, Seoul, Korea, May 4, 2007, and Department of Physics, Center for Quantum Spacetime, Sogang University, Seoul, Korea, May 9, 2007.

3. *Amplification of tachyonic perturbations at super-Hubble scales*, Seminar at Department of Physics, Sungkyunkwan University, Suwon, Korea, May 11, 2007.

4. *Deviations from slow roll inflation and features in the primordial spectrum*, Invited talk in The First Indo-Brazil Workshop on Cosmology, Inter-University Centre for Astronomy and Astrophysics, Pune, July 16–21, 2007.

5. *Vanilla cosmology, and beyond*, Invited talk in Indian Conference on Cosmology and Galaxy Formation, Harish-Chandra Research Institute, Allahabad, November 3–5, 2007.

6. *Path integral duality and Planck scale corrections to the stress-energy tensor around the BTZ black hole*, Invited talk in Field Theory Aspects of Gravity VI, Harish-Chandra Research Institute, Allahabad, November 13–17, 2007.

7. *Corrections to the Bekenstein-Hawking entropy in the brick wall approach*, Invited presentation in the Quantum Gravity session at the International Conference on Gravitation and Cosmology, Inter-University Centre for Astronomy and Astrophysics, Pune, December 17–21, 2007.

8. *Sub-leading contributions to the black hole entropy in the brick wall approach*, Seminar at Chennai Mathematical Institute, Chennai, January 14, 2008.

9. *A brief history of the universe*, Colloquium at Chennai Mathematical Institute, Chennai, January 16, 2008.

10. *On the evolution of curvature perturbations at super-Hubble scales*, Seminar at Department of Physics, Indian Institute of Technology, Chennai, January 18, 2008.

11. *Cooling and reheating the universe*, Invited talk in Prospects and Problems of Gravitation and Cosmology, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, January 29–30, 2008.

Other Activities:

1. I organized the meeting *Field Theory Aspects of Gravity VI* at HRI during November 13–17, 2007.

2. I was one of the coordinators of the Working Group on Astroparticle Physics, Cosmology and Neutrinos at *The Tenth Workshop in High Energy Physics Phenomenology* that was held at the Institute of Mathematical Sciences, Chennai, during January 2–13, 2008.

3. I guided the HRI graduate student Satyanarayan Mukhopadhyaya through a reading course on *Cosmology* during January–May 2008.

4. I guided the following two students on a project under the Visiting Students' Program:

   (a) Sk. Maidul Haque, M.Sc. Physics, I year, Department of Physics, Indian Institute of Technology, Delhi, May–June 2007. Topic: *Galactic dynamics*.

   (b) Ishan Srivastava, B.Tech. Engineering Physics, III year, Departments of Physics and Electrical Engineering, Indian Institute of Technology, Chennai, June–July 2007. Topic: *Gravitational lensing and microlensing*.

5. I supervised the KVPY student Hamsa Padmanabhan during May–June 2007. Topic: *Elements of quantum mechanics*.

6. I was incharge of conducting (the Physics part of) the HRI Science Talent Test 2007.

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Anurag Tripathi

Research Summary:

Di-photon production at the Large Hadron Collider the LHC is an important process in discovering physics beyond Standard Model. We studied this process in Unparticle scenario and extra-dimension models at Leading order and Next to leading order in strong coupling constant. Various kinematical distributions were obtained for these beyond Standard Model scenarios such as diphoton mass distribution and rapidity distribution.

Publications:

1. M. C. Kumar, P. Mathews, V. Ravindran and A. Tripathi, *Unparticle physics in diphoton production at the CERN LHC,* Phys. Rev. D 77, 055013, (2008)

Preprints:

1. M. C. Kumar, P. Mathews, V. Ravindran and A. Tripathi, *Unparticles in diphoton production to NLO in QCD at the LHC,* arXiv:0804.4054

Conference/Workshops Attended:

1. *School on QCD at LHC*, India, November, 2007.
2. *WHEPP-X* , India, January 2008.

Visits to other Institutes:

1. SINP, Kolkata, India, July 2007.

Invited Lectures/Seminars:

1. *Diphoton production at the LHC in Unparticle scenario*, WHEPP-X, IMSC, Chennai, January 2008.

Other Activities:

1. Talk in Pheno Group, December, 2007.
2. Extension Talk , March, 2008.

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LECTURES / TALKS / SEMINARS

AT THE INSTITUTE

MATHEMATICS

1.	Amit Kulshrestha	Valuation-like functions on central simple algebras and an application
2.	Maneesh Thakur	J. Tits and R.M. Weiss conjecture
3.	Florian Luca	On sums of prime factors
4.	Florian Luca	On the largest prime factor of Mersenne numbers
5.	Tarakanta Nayak	Dynamics of Transcendental Meromorphic functions
6.	Jonathan Weitsman	Probability, Quantum Field Theory, and Geometry - series of 6 lectures
7.	Jean-Marc Fontaine	Modular Forms, Galois Representations and p-Adic Hodge Theory
8.	Manjul Bharghava	Sums of Squares and the 290-Theorem forms
9.	Florian Luca	Arithmetic properties of Lucas numbers -lecture series of 3 lectures
10.	Kaiming Zhao	Deformed Kac-Moody algebras
11.	Kaiming Zhao	Representations of deformed Kac-Moody algebras
12.	Nils-Peter Skoruppa	Finite quadratic modules, Weil representation and Applications - lecture series of 6 lectures
13.	Sameer Chavan	A Friedrichs extension related to unbounded subnormals

14.	Manoj Kumar Yadav	Central Automorphism of finite groups-I
15.	D.N. Verma	Study of Weyl groups, Coxeter groups, & Rootsystems: basic tools for Lie Theory and many related topics
16.	Sridharan	A compact course on Global Field Theory
17.	K. Soundararajan	The distribution of values of the Riemann Zeta-function
18.	Satya Deo	The number n for which the Euclidean n-space is a field
19.	Kalyan Chakraborty	On the ABC conjecture
20.	Akio Fujii	On the Farey series
21.	R. S. Kulkarni	Fundamental Domains for Subgroups of Modular Group -Two lectures
22.	V. Balaji	Abelian and Non-abelian Mathematics: A Glimpse
23.	Ram Murty	Is Euler's constant transcendental?
24.	Ram Murty	The Art of Research
25.	Kaiming Zhao	Representations of Generalized Virasoro Algebras
26.	Kaiming Zhao	Weyl Type Lie Algebras
27.	V. Kumar Murty	Artin L-functions near $s = 1$
28.	V. Balaji	Vector and Principal Bundles over Curves -lecture series of 10 lectures
29.	Francesco Pappalardi	Words and Primitive Roots

LECTURES / TALKS / SEMINARS
AT THE INSTITUTE
PHYSICS

1.	Rajeev Kumar Jain	Suppressing the lower multipoles in the CMB anisotropies
2.	Manimala Mitra	Renormalization and Renormalization group in QFT
3.	Jayanti Prasad	Effects of finite box size in cosmological n-body simulations: Halo formation and destruction rates
4.	Nishikanta Khandai	Adaptive TreePM: A High Resolution Collisionless code for Cosmological N-Body Simulations Gauge Theory
5.	Rajeev Kumar Jain	Amplification of tachyonic perturbations at super-Hubble scales
6.	Shashank Shalgar	Neutrino Oscillation Toolkit
7.	Anamitra Mukherjee	Hysteresis, pinning, and field melting of charge order
8.	Arijit Saha	Zero-biased transport through a dot at the junction of multiple quantum wires
9.	Kalpataru Pradhan	Two distinct effects of disorder on a complex insulating state
10.	A.N.Ramaprakash	IUCAA Girawali Observatory
11.	Jinn-Ouk Gong	Multiple scalar particle decay and perturbation generation

12.	Tapas K. Das	Is Violation of Newton's Second Law Possible?
13.	Manimala Mitra	Standard Model Higgs Search at Colliders
14.	Viveka Nand Singh	Density functional theory and its application to calculate band structure
15.	Arjun Bagchi	Tachyon Condensation and String Field
16.	Anurag Tripathi	The Two Cutoff Phase Space Slicing Method
17.	Rajeev Kumar Jain	Constraints on Features in the Primordial Spectrum of Inflationary Perturbations
18.	Sudhir K. Vempati	Flavour physics and Dark matter as probes of SUSY-GUTs
19.	Manu Mathur	Loop space gravity state in lattice gauge theory
20.	Dinesh Srivastava	Electromagnetic Probes of Hot Hadronic Matter
21.	Diptiman Sen	Quantum charge pumping
22.	T. Padmanabhan	Fun with Newtonian Gravity
23.	Jinn-Ouk Gong	Generation of perturbation after multi-field inflation
24.	Alok Gupta	Variability of AGNs on Diverse Time Scales
25.	A. Upadhyay	Charm meson masses in heavy hadron chiral perturbation theory
26.	Deepak Dhar	Orientational ordering of hard long rods on a lattice
27.	S. Mohanty	Thermal Effects on Inflation Power spectrum
28.	S. Sriramkumar	Perturbations in bouncing universes

29.	J.S. Bagla	Cosmic Reionization and the 21cm signal Hydrogen and the Spin Temperature
30.	Girish Kulkarni	Anisotropic Shapes of Quasar HII Regions
31.	Jayant K. Pendharkar	Anticorrelated Hard X-ray time lags in Galactic BH sources: Evidence for trunccated accretion disk models
32.	Shrirang S. Deshingkar	Can we see naked singularities?
33.	Rajeev Kumar Jain	Evolution of large scale curvature fluctuations during the decay of inflation
34.	Jinn-Ouk Gong	What would we learn by detecting a gravitational wave signal in the cosmic microwave background anisotropy?
35.	Jinn-Ouk Gong	Minimal Extra Dimensional Cosmology from Hidden Sector
36.	Paramita Dey	Distinguishing Littlest Higgs model with T-parity from supersymmetry at LHC using trileptons
37.	Nishikanta Khandai	The Phase-Space Densities of CDM Halos
38.	Rajarshi Tiwari	Cosmological Parameter Estimation with High Redshift Supernovae $Co_2Fe_{0.4}Cr_{0.6}Al$: an augmented space approach
39.	Asmita Mukherjee	Hadron Optics: Diffraction Patterns in Deeply Virtual Compton Scattering
40.	Michal Dovciak	Relativistic effects on radiation from accretion discs in strong gravity
41.	Ishwaree Neupane	Time-dependent solutions and string compactification on a conifold
42.	Sameer Murthy	Fundamental Strings as Holograms

43.	Tao Han	The search for lepton-number violating processes
44.	Prabuddha Sanyal	Understanding electronic, magnetic and disorder aspects of double perovskites
45.	Markus Buttiker	Two-particle Aharonov-Bohm effect
46.	Biswajit Pandey	The luminosity star formation relation and filamentarity of the star forming galaxies in the Sloan Digital Sky Survey Data Relese Five
47.	Sashideep Gutti	Quantum gravitational Collapse and Hawking radiation in (2+1) Dimensions
48.	Jayanti Prasad	Stellar feedback in Dwarf Galaxy formation
49.	Swapan Chattopadhyay	Accelerators of the Twenty First Century: Challenges, Reach and Scientific Promise
50.	Amitabh Virmani	A Stress Tensor for Asymptotically Flat Gravity
51.	Sreedhar Datta	Ageing in quenched systems and universality
52.	Jayanti Prasad	Aspects of Gravitational Clustering in an Expanding Universe

COLLOQUIUM
JOINTLY ORGANISED BY
MATHS & PHYSICS

1.	R. Balasubramanian	The circle method and some classical problems in Number Theory
2.	J. Weitsman	Lattice points in convex polytopes, the Euler Maclaurin formula and the Ehrhart theorem for symbols
3.	Florian Luca	Values of the Euler function in arithmetic progressions
4.	V. Kumar Murty	Artin L-functions near $s = 1$
5.	Kaiming Zhao	Representations of generalized Virasoro algebras
6.	Samarjit Kar	Reminisceces of Some Indian Scientists
7.	Jean Dreze	Public-spiritedness and Development
8.	Pajushpani Bhattacharjee	Supernovae, Gamma Ray Bursts, Cosmic Rays and Neutrinos
9.	Ashok Das	Thermal Operator Representation of Finite Temperature Feynman Graphs
10.	Tao Han	High Energy Physics: The next Two Decades
11.	Tanusri Saha-Dasgupta	Understanding Physics and Chemistry of Complex Materials by N-MTO method
12.	T. Ramasami	Painting a long term horizon for Indian science

STUDENT'S CORNER

Ph.D. Programme

The following students have submitted their thesis towards their Ph.D. degree:-

Sr. No.	Name of the student	Thesis	Thesis Submitted on
1	Pomita Ghosal	"A Study of Matter Effects in Neutrino Oscillations"	31/10/2007 (University of Allahabad.)
2	Raghavendra Srikant H	"Some Studies in Physics Beyond the Standard Model"	05/10/2007 (University of Allahabad.)
3	Anupama Panigrahi (Visiting Student)	"Some Problems in Combinatorial Number Theory"	12/10/2007 (University of Allahabad.)

Integrated Ph.D. Course under HBNI

The following students have completed their M.Sc. programme under the Integrated Ph.D. Programme of Homi Bhabha National Institute:-

Sr.No.	Name of the student	Field of Research
1	Mr. Soumya Das	Mathematics
2	Mr. Girish Prasad Kulkarni	Physics

PUBLICATIONS AND PREPRINTS IN MATHEMATICS

PUBLICATIONS :

Sukumar Das Adhikari

1. S. D. Adhikari and Y. G. Chen, *Davenport constant with weights and some related questions - II*, J. Combinatorial Theory, Ser. A, **115**, 178–184 (2008).

2. S. D. Adhikari, R. Balasubramanian and P. Rath, *Some combinatorial group invariants and their generalizations with weights*, Additive Combinatorics, (Eds. Granville, Nathanson, Solymosi), 327 – 335, CRM Proceedings and Lecture Notes, Volume 43, American Mathematical Society, 2007.

3. S. D. Adhikari, R. Balasubramanian, F. Pappalardi and P. Rath, *Some zero-sum constants with weights*, Proc. Indian Acad. Sci. (Math. Sci.), to appear.

4. Sukumar Das Adhikari, Stephan Baier and Purusottam Rath, *An extremal problem in lattice point combinatorics*, Diophantine Equations, N. Saradha Ed., Tata Institute of Fundamental Research, to appear.

5. S. D. Adhikari and P. Rath, *A problem on the fractional parts of the powers of $3/2$ and related questions*, Proc. Int. Conf. - Number Theory and Discrete Geometry, the proceedings of a conference held at Chandigarh University in honour of Prof. R. P. Bambah, to appear.

Punita Batra

1. S. Eswara Rao and Punita Batra, *Classification of irreducible integrable modules for twisted toroidal Lie algebras with finite dimensional weight spaces,* Pacific Journal of Mathematics, **Vol. 237, No.1,** 151-181, (2008).

Kalyan Chakraborty

1. K. Chakraborty *On the Diophantine equation $x + y + z = xyz = 1$* Annales Univ. Sci. Budapest., Sect. Comp. **Vol. 27**, 145–154 (2007)

2. Kalyan Chakraborty, Florian Luca and Anirban Mukhopadhyay *Exponents of class groups of real quadratic fields,* Intl. Journal of Num. Theory , To Appear, (2008)

3. Kalyan Chakraborty, Florian Luca and Anirban Mukhopadhyay *Class numbers with many prime factors,* Journal of Num. Theory , To Appear

Sameer Laxman Chavan

1. S. Chavan, *On Operators Close to Isometries,* Studia Mathematica **186**, 275-293, (2008)

Satya Deo

1. Deo, Satya and Maitra, J.K., *Freeness of spline module from a divided domain to a subdivided domain*, Frontiers in interpolation and approximation 59-73, Pure and Appl Math, Chapman and Hill/CRC, Baton Rouge, FL, 2007.

Rukmini Dey

1. Rukmini Dey, *HyperKähler prequantization of the Hitchin systems and Chern-Simons gauge theory with complex gauge group,* Adv. Theor. Math. Phys. **11**, 819-837, (2007)

Ioulia Baoulina

1. Ioulia Baoulina, *On the equation* $x_1^{m_1} + \cdots + x_n^{m_n} = ax_1 \cdots x_n$ *over a finite field,* Finite Fields Appl. **13**, 887-895, (2007).

Ramakrishnan B.

1. S. Gun and B. Ramakrishnan, *On special values of certain Dirichlet L-functions,* The Ramanujan Journal **15**, 275–280, (2008)

Ratnakumar Peetta Kandy

1. P. K. Ratnakumar, *On Schrödinger propagator for the special Hermite operator, J. Fourier Anal. and Appl.,* Journal name **Vol 14, No. 2**, 286-300, (2008)

Brundaban Sahu

1. (with S. Gun, Florian Luca, P. Rath, R. Thangadurai) *Distribution of Residues Modulo* p*,* Acta Arith. **129**, no. 4, 325–333, (2007).

Mahender Singh

1. Mahender Singh, $\mathbb{Z}_2$ *actions on complexes with three non-trivial cells,* Topology and its Applications **155**, 965-971, (2008).

D. Surya Ramana

1. D.S. Ramana, *Arithmetical Applications of an Identity for the Vandermonde Determinant,* Acta Arithmetica **130.4**, 351-359, (2007).

R. Thangadurai

1. S. Gun, F. Luca, P. Rath, B. Sahu and R. Thangadurai, *Distribution of residues modulo p.* Acta Arith. 129 (2007), no. 4, 325–333.

2. R. Thangadurai, *Irreducibility of polynomials whose coefficients are integers*. RMS Math. Newsletter 17 (2007), no. 2, 29-37.

3. P. Rath, K. Srilakshmi and R. Thangadurai, *On Davenport's constant*, Int. J. Number Theory, **4**, No. 1 (2008) 107-115.

4. W. D. Gao, R. Thangadurai, J. Zhuang, *Addition theorems on the cyclic groups of order p^ℓ*, Discrete Math. **308** (2008) 2030-2033.

5. F. Luca, I. E. Shparlinski and R. Thangadurai, *Quadratic non-residues verses primitive roots mod p*, Journal of Ramanujan Mathematical Society, **23**, No. 1, (2008), 97-104.

Manoj Kumar (Yadav)

1. Manoj K. Yadav, *Class preserving automorphisms of finite p-groups,* J. London Math. Soc. **75**, 755-772, (2007)

2. Manoj K. Yadav, *On automorphisms of finite p-groups*, J. Group Theory **10**, 859-866, (2007)

3. Manoj K. Yadav, *On automorphisms of some finite p-groups,* Proc. Indian Acad. Sci. (Math. Sci.) **118**, 1-11, (2008)

PREPRINTS :

Punita Batra

1. Punita Batra, Xiangqian Guo, Rencai Lu and Kaiming Zhao, *Highest weight modules over pre-exp-polynomial Lie algebras,* submitted for publication.

Kalyan Chakraborty

1. Kalyan Chakraborty, Florian luca *Perfect powers in solutions to pell equations* Preprint

2. Kalyan Chakraborty, Shigeru Kanemitsu and J. -H Li *Manifestations of Parseval Identity* Preprint

3. Kalyan Chakraborty, Florian Luca, *On the solutions of the Diophantine equation* $a+b+c+d = abcd = 1$ *in the ring of integers of quadratic fields,* (in preparation)

Sameer Laxman Chavan

1. S. Chavan, *A Spectral Exclusion Principle for Unbounded Subnormals,* Proceedings of the American Mathematical Society, DOI: 10.1090/S0002-9939-08-09488-4

2. S. Chavan, *Co-analytic, Right Invertible Operators are Supercyclic,* PAMS7942

3. S. Chavan, *On Operators Cauchy Dual to 2-hyperexpansive Operators-II,* AMSTR8213

Chandan Singh Dalawat

1. Chandan Singh Dalawat, *Local discriminants, kummerian extensions, and abelian curves*, 61 pp., arXiv:0711.3878.

2. Chandan Singh Dalawat, *Wilson's theorem*, 5 pp., arXiv:0711.3879.

Satya Deo

1. M.Baillif, S.Deo and D.Gauld *Mapping class groups of some nonmetrizable manifolds*

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ABOUT THE LIBRARY

The institute's library is one of the best equipped libraries in the region. Being a research oriented institute, it provided the required support to the academic and research activities. It remained open on all working days from 8 AM to 2 AM including Saturday. It also remained open during Sundays and gazetted holidays from 10 AM to 6 PM. It had added 583 volumes in its fold which include 550 purchased books and 33 gifted books. It increases the total number of books to 16342. It had also added 1697 bound volumes of the Journals during the period from 1^{st} April 2007 to 31^{st} March 2008. It has increased bound volumes collection to 29242. The institute's library has a total collection of 45584 (B16342 + J29242) of books and bound volumes. The library had subscribed 235 journals during this period. It includes 111 as online journals.

During the last year basic emphasis had been provided to the conversion of the Video Cassettes to VCD format for durability. We also started building of the Digital Depository of the HRI, which will include the submitted articles, theses, lectures etc. 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 online. We have been providing online access of the periodicals to our users for 111 titles.

We had provided the web enabled library catalogue to our users. The library can be turned as completely automated library system, which includes acquisition, cataloguing, circulation, search modules etc. This online 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 honored through e-mails. 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 Electromagnetic Tattle Tapes to reduce the losses. It has been completely functional.

ABOUT COMPUTER SECTION

1. Further expansion of the local area network in the students' offices of the first floor library building was commissioned and made operational.
2. Few Desktops were purchased and installed with Linux operating system in the offices of first floor library building.
3. Three high speed A4 size laser printers were purchased and installed as network printers for all users.
4. Newer versions of different flavors of Linux operating systems were loaded on the desktops.
5. Few more laptops were procured for giving presentation and doing computation work while on visit.
6. Internet bandwidth through Sify Ltd. was upgraded to 2 Mbps to suffice the increased Internet usage.
7. Computing related to conferences were held in the conference computer room.
8. Network Audit test was conducted for all the network points.
9. New versions of several applications software were loaded on users' systems and on conference room computers.

Current activities and plans

1. Purchase of more (12 Mbps/16 Mbps) Internet bandwidth is under process to suffice the increased Internet usage.
2. Purchase of a few desktops is under plan.
3. Up-gradation of existing CRT colour monitors with 17″ TFT monitors are under plan.
4. Purchase of a few high end ONLINE central UPS with parallel redundancy (N+1) is under plan to upgrade the old and aging 20 KVA UPS systems.
5. Expansion of wireless networking to cover up most of the places of Institute building and library building is being processed.

6. Purchase of high end rack mounted computer servers for running all the major computing services are under plan.
7. Up-gradation of existing LAN switches with Optical Fiber Cable back bone is under plan.
8. Up-gradation of existing file server with high end Network Storage Systems (NAS) with redundancy and more usable data capacity is under plan.
9. Purchase of a colour laser A3 size printer is under plan.

About Construction Work at the Campus

1. Engineering consulting services for the work related to construction of following buildings (Hostel-3, Institute expansion, Engineering and Community Centre Annexe)was finalized and work order was placed to M/s Architect Atelier Pvt. Ltd., Chandigarh. The work is under progress.

2. The work for 33 KV uninterrupted power supply line directly from 132 KV Substation under progress (by UPPCL). The institute has also started other related work under their scope for commissioning the 33 KV power line.

3. New pantry was constructed by some modification in the existing area of Institute building below the ground floor(one end of building).

4. Following miscellaneous works were also carried out during the financial year:-

    - False ceiling in rooms at 3rd floor of Institute Buildings.
    - Intercom telephone facility for the Hostel-1.
    - Providing & fixing of mail boxes in library building.
    - Extension and Renovation work in children's park along with fencing work.
    - Conversion of Hall in a regular flat in one of PDF building.
    - Provision of fixing A.C. in window of type E quarters.
    - Provision of Cooler, Window in balcony of type B & C.
    - Construction of Balcony enclosure for B & C type quarters.
    - Fabricating and fixing watch tower.
    - Provision of closing the shelves in dining area of D type quarters.
    - Drainage system from swimming pool outlet to culvert.
    - Additional security and street lighting for the campus.
    - Internal Electrification for the new Godrej cubicles in library buildings.
    - Fire Alarm system for Institute buildings.
    - Extension of panel of pump house and UPS Room.

VIGILANCE ACTIVITIES AT THE CAMPUS

There is nothing to report from vigilance point of view for the period upto March 31, 2008.