Academic Report 2009–10

Harish-Chandra Research Institute

Chhatnag Road, Jhunsi, Allahabad 211019

Contents

About the Institute

Early Years

The Harish-Chandra Research Institute is one of the premier research institute in the country. It is an autonomous institute fully funded by the Department of Atomic Energy, Government of India. Till October 10, 2000 the Institute was known as Mehta Research Institute of Mathematics and Mathematical Physics (MRI) after which it was renamed as Harish-Chandra Research Institute (HRI) after the internationally acclaimed mathematician, late Prof Harish-Chandra.

The Institute started with efforts of Dr. B. N. Prasad, a mathematician at the University of Allahabad with 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 as the first formal Director. After an interim period in January 1983, Prof. S. S. Shrikhande joined as the next Director of the Institute. During his tenure the dialogue with the Department of Atomic Energy (DAE) entered into decisive stage and a review committee was constituted by the DAE to examine the Institutes future. 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, about 66 acres of land was acquired in Jhunsi, Allahabad and the Institute 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 Institutes activities picked up pace. This phase of rapid growth still continues.

New Phase

After a distinguished tenure of about nine years Prof. Mani retired in August 2001 and the charge was taken over by Prof. R. S. Kulkarni. After Prof. Kulkarnis tenure, Prof. Amitava Raychaudhuri has taken over as Director from July

19, 2005. The Institute continues to be devoted to fundamental research in diverse areas of mathematics and theoretical physics. Research is carried out by faculty members, visiting members, post-doctoral fellows and Ph. D. students. Since 1992 the Institute has attracted worldwide attention, as is evident from the recognition received by many of its members. Among them are Ashoke Sen, A. Raychaudhuri, B. Mukhopadhyaya, Pinaki Majumdar, Rajesh Gopakumar are all winners of the prestigious S. S. Bhatnagar award. Ashoke Sen was also awarded the Padmashri and was elected to the Fellowship of the Royal Society. Prof. Rajesh Gopakumar had earlier won the Swarnajayanti fellowship of Department of Science and Technology and the International Centre for Theoretical Physics (ICTP) prize for 2006. Recently, Prof. Ashoke Sen was chosen for the prestigious Infosys prize in 2009.

Research in Mathematics

The mathematics group at HRI carries out research in several areas. In algebra, work is done on algebraic groups and related structures, the theory of groups and group rings, representation theory, and infinite-dimensional Lie algebras. Work in analysis is in the field of harmonic analysis of Lie groups.

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

Research in Physics at HRI is carried out in the fields on astrophysics, condensed matter physics, quantum information and computing, high energy phenomenology and string theory. In astrophysics, work is done on the cosmic microwave background, large scale structure formation and galaxy evolution. 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. Research in neutrino physics, strong interactions, lattice gauge theory, supersymmetry and various aspects of physics beyond the standard model is done in high-energy phenomenology. The Institute is a member of the India-based Neutrino Observatory (INO) collaboration.

The Institute has a residential campus in Jhunsi, Allahabad with a library, state of the art computational facility and fast Internet link to the outside world. There is an active graduate program and a large traffic of visiting scientists and students.

Director's Report

Harish-Chandra Research Institute (HRI) continued its excellent work in 2009-10. One indicator of the Institute's stature today is the steady increase in the number of national and international conferences, workshops, and meetings at HRI. These conferences attract prominent scientists of all levels (senior faculty to students) from India and all over the world. Keeping this in mind, the facilities in the HRI auditorium have been upgraded. A better projection facility, wireless internet connectivity, and new Tower ACs have recently been added.

The Institute is widely recognized as a premier research institution. The innovative research publications which attract good citations, the invitations to conferences and meetings nationally and internationally, the awards and recognitions, and the popularity among intending post-docs and students are all a testimony of the Institute's quality. The Institute is generously supported by the Department of Atomic Energy which has enabled HRI to meet the demands that such a status entails.

I am particularly happy that a promotion policy for the administrative and technical members of HRI has been approved. Over the last year a large number of staff of these categories have received the benefits from this policy.

The XI Plan construction projects intend to expand the library, computer, and office space, to add a new students' hostel, expand the community centre, etc.. The tender documents for these constructions have been prepared. The work for these will commence in the year ahead.

In the 2009-10 academic year six students joined the Ph.D. programme in mathematics while ten joined the Ph.D. programme in physics. All Ph.D. students of HRI register with the Homi Bhabha National Institute (HBNI). In this period eight students finished their Ph.D.s in physics and two did so in mathematics.

This year there was a review of HBNI by a committee constituted spe-

cially by the UGC. As a part of this, on behalf of the Committee Professor N. Mukunda, IISc, Bangalore visited the Institute for two days in March 2010 and reported on his observations. The Report spoke highly about the accomplishments of HRI.

The recurrent long power outages had been a longstanding issue for the Institute. Though DG sets used to be pressed into service during these periods, power was certainly a cause for concern. I am happy to report that a 33kV dedicated connection from the Uttar Pradesh Power Corporation Limited is now functional.

Infosys Foundation had made a monetary grant of Rs. 12 Lakhs to HRI in 2005 which was utilized for three purposes: (a) to support the travel of foreign participants to the International Workshop on Teichmuller Theory and Modular problems which was organized at HRI in January 2006, (b) for book grants to senior graduate students in 2005-06, and (c) for modest financial support for foreign travel for senior graduate students to attend summer schools and meetings. Since then, Infosys Foundation expressed an interest to make a second similar monetary grant. The Institute warmly welcomed this step. A grant of Rs. 25 Lakhs has now been received from Infosys Foundation.

July 22, 2009 was a day when total solar eclipse could be seen from areas near Allahabad. On this occasion HRI arranged an eclipse observation event at St. John's Academy, a school in nearby Karchana. Members of HRI made an introductory presentation for the school children. The children were curious about the event and had many questions. They watched the event with enthusiasm. HRI also joined the efforts of other organizations of the city in arranging for school children the observation of the eclipse from a point in Madhya Pradesh, a few hours away from Allahabad.

During the last year one HRI-Triveni Lecture and two HRI-Girdharilal Mehta Lectures were arranged. Professor Alexei Smirnov, ASICTP, Italy delivered the 4th HRI-Triveni Lecture entitled 'Neutrinos: Another image of the Universe' on 11th February 2010. On 8th December 2009 the 7th HRI-Girdharilal Mehta Lecture on 'The Physics of Synchrony: from Huygens to Higgs, via Kamerlingh Onnes, Bose and Einstein' was delivered by Professor Peter B. Littlewood, Cambridge University, UK. Professor N. Mukunda, Indian Institute of Science, Bangalore spoke on 'Science and the Human Predicament' in the 8th HRI-Girdharilal Mehta Lecture on March 26, 2010.

The Institute intends to develop in the area of Quantum Information/Quantum Computing. Two faculty members specialized in this area – Dr. Ujjwal Sen and Dr. Aditi Sen (De) – have joined and steps have been initiated to secure an XI Plan project support for research in this subject. Also, during the year Dr. G.V. Pai, who is a condensed matter physicist, has joined the Institute.

Dr. Srubabati Goswami, who was granted lien for one year to join the Physical Research Laboratory, requested a further years extension, which was granted. Dr. Debashis Ghosal, who was on lien and had joined the Jawaharlal Nehru University, tendered his technical resignation. This has been accepted. Dr. Justin David, had joined the Centre for High Energy Physics, Indian Institute of Science, Bangalore, on lien from HRI. He has since tendered his technical resignation which has been accepted. Dr. Manoj Gopalakrishnan had joined the Indian Institute of Technology Madras, Chennai keeping a lien on his position at HRI. He has also submitted his technical resignation and this has been accepted. The Stores and Purchase Officer of HRI, Mr. Deepak Srivastava, moved to a sister DAE institution. Mr. P.S. Babu has joined as the Stores and Purchase Officer.

Like other years, HRI scientists have again been decorated with a number of awards and distinctions. It is a matter of great pride that Professor Ashoke Sen has been awarded the Infosys Award for Mathematical Sciences for 2009. Professor Sen has also been conferred a Doctor of Science (*honoris causa*) by the Indian Institute of Technology, Kharagpur. Professor Rajesh Gopakumar has been selected for the Shanti Swarup Bhatnagar Award in Physical Sciences for 2009. Professor Gopakumar has also been elected to the Fellowship of the Indian National Science Academy (INSA). Dr. Manoj Kumar was selected for the 2009 INSA Young Scientist Award in Mathematics. Dr. Suvrat Raju, postdoctoral fellow at HRI, has been awarded the Ramanujan Fellowship by the Department of Science of Technology. Professor Amitava Raychaudhuri has been selected for the J.C. Bose Fellowship also of the Department of Science and Technology.

It may not be out of place to take note of some of the accomplishments of the past five years. The Institute members have won many awards and distinctions during this period. The Institute is now a top destination for intending Ph.D. students. The students after their Ph.D.s have been picked up by leading institutions all over the world with post-doctoral fellowships. The HRI-Triveni and HRI-Girdharilal Mehta Lectures have been initiated. A new group on the fast-developing area of Quantum Information and Quantum Computation has been created with two faculty members and a third, who has been offered and accepted, is to join soon. Through the Homi Bhabha National Institute affiliation, the Institute has established a number of academic linkages with other DAE units and autonomous institutes. HRI undertook an External Peer Review in 2007, chaired by Professor M.S. Narasimhan, which commended the Institute for its rapid development and quality research. A promotion policy for the administrative and technical staff of the Institute has been implemented and many have already benefited. Under the XI Plan the Institute's project funding has been increased five-fold compared to the X Plan. Every academic group has an XI Plan project which has helped, among other things, support academic exchanges and increased the number of conferences and meetings at the Institute. A much enhanced XI Plan High Performance Computing (Clus-

ter) facility is providing the essential computational power for the Institute's research. A Regional Centre for Accelerator-based Particle Physics has been set up under the XI Plan. A dedicated 33 kV power connection has been established for the Institute. These days reliable and fast internet connectivity has become essential to keep up with international research. Accordingly, the internet bandwidth – which was 2.25 MBps in 2005 – now stands at 36 MBps and will be increased even further. Enough redundancy in Internet Service Providers has been built in so that the downtime of any one of them does not affect the work of the Institute. The Institute, including the auditorium, now has wireless connectivity. A new larger tea-pantry has been set up which has become very popular among all Institute members. Construction of a students' hostel and work towards the expansion of the library, office, and computer centre space is expected to start very soon. The issue which needs most immediate attention is that the Institute is now in dire need of new faculty positions.

A. RAYCHAUDHURI
DIRECTOR

Governing Council

1.	Prof. M. S. Raghunathan (Chairman)	School of Mathematics Tata Institute of Fundamental Research Homi Bhabha Road Mumbai 400005
2.	Prof. R. Balasubramanian	Institute of Mathematical Sciences CIT Campus, Taramani Chennai 600113
3.	Dr. J. N. De	BH-135, Sector II Salt Lake Kolkata 700091
4.	Prof. Narendra Kumar	Raman Research Institute Sadashivnagar Bengaluru 560080
5.	Prof. H. S. Mani	2 Fourth Cross Street Durga Colony, Sembakkam Chennai 600073
6.	Mr. S. L. Mehta	4 Clive Row Kolkata 700001
7.	Mr. Avnish Mehta	4 Penn Road Kolkata 700027
8.	Mr. Rama Kant Mishra	23/1E P. C. Banerjee Road

		Allen Ganj Allahabad 211001
9.	Dr. Mian Jan	Director, Higher Education, U.P. Near G.P.O, Civil Lines Allahabad 211001
10.	Prof. A. Raychaudhuri	Harish-Chandra Research Institute Chhatnag Road, Jhunsi Allahabad 211019
11.	Mr. V. R. Sadasivam	Joint Secretary (F) Govt. of India, DAE Ch. Shivaji Maharaj Marg Mumbai 400001
12.	Dr. P. Mukherjee	Joint Secretary (R& D) Govt. of India, DAE Ch. Shivaji Maharaj Marg Mumbai 400001

Academic Staff

Mathematics Faculty

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

Physics Faculty

1. Prof. Amitava Raychaudhuri
2. Prof. B. Mukhopadhyaya
3. Prof. S. Naik
4. Prof. Sudhakar Panda
5. Prof. Raj Gandhi
6. Prof. Ashoke Sen
7. Prof. Sumathi Rao
8. Prof. Dileep Jatkar
9. Prof. Pinaki Majumdar
10. Prof. V. Ravindran
11. Prof. Jasjeet Singh Bagla
12. Prof. Rajesh Gopakumar
13. Dr. Srubabati Goswami
14. Dr. L. Sriramkumar

15. Dr. T. P. Pareek
16. Dr. Prasenjit Sen
17. Dr. Tapas Kumar Das
18. Dr. Aseshkrishna Datta
19. Dr. Sandhya Choubey
20. Dr. Tirthankar Roy Choudhury
21. Dr. Ujjwal Sen
22. Dr. Aditi Sen De
23. Dr. G. Venketeswara Pai

Mathematics Research Scholars

1. Mr. Vijay Kumar Sohani
2. Mr. Karam Deo Shankhadhar
3. Ms. Archana Morye
4. Mr. Soumya Das
5. Mr. Amrutiya Sanjaykumar Hansraj
6. Mr. Chintamani Mohan Namdev
7. Mr. Jaban Meher
8. Mr. Moriya Bhavinkumar Kishorsinh
9. Mr. Jay Gopalbhai Mehta
10. Mr. Pradip Kumar
11. Mr. Akhilesh P.
12. Mr. G. Kasi Viswanadham
13. Mr. Pradeep Kumar Rai

Physics Research Scholars

1. Mr. Rajesh Kumar Gupta
2. Mr. Arjun Bagchi
3. Mr. Ayan Mukhopadhyay
4. Mr. Turbasu Biswas
5. Mr. Girish Kulkarni
6. Mr. Subhaditya Bhattacharya
7. Ms. Ipsita Mandal
8. Ms. Manimala Mitra
9. Mr. Vivekananda Singh
10. Mr. Rajarshi Tiwari
11. Mr. Shamik Banerjee
12. Mr. Shailesh Lal
13. Mr. Dhiraj Kumar Hazra
14. Mr. Satyanarayan Mukhopadhyay

15. Mr. Sanjoy Biswas
16. Mr. Joydeep Chakrabortty
17. Ms. Nishita Desai
18. Mr. Ram Lal Awasthi
19. Mr. Manoj Kumar Mandal
20. Mr. Arijit Kundu
21. Mr. Atri Bhattacharya
22. Mr. Saurabh Niyogi
23. Mr. Arunabha Saha
24. Mr. Ujjal Kumar Dey
25. Mr. Saurabh Pradhan
26. Mr. Vikas Chauhan
27. Mr. Sourav Mitra
28. Mr. Sabyasachi Tarat
29. Mr. Mohana Rao Barri
30. Mr. Nyayabanta Swain
31. Mr. Abhishek Chowdhury
32. Mr. Swapnamay Mondal
33. Ms. Akansha Singh
34. Ms. Shrobona Bagchi
35. Mr. Raghunath Ghara
36. Mr. Dharmadas Jash
37. Mr. Mehedi Masud
38. Mr. Avijit Misra

Mathematics Visiting Fellows

1. Dr. Pavinder Singh
2. Dr. Vivek Kumar Jain
3. Dr. Ramkrishna Pandey
4. Dr. Geeta
5. Dr. Ashish Gupta
6. Dr. Rajesh Kumar Srivastava

Physics Visiting Fellows

1. Dr. Abhijit Samanta
2. Dr. Sashideep Gutti
3. Dr. Suvrat Raju
4. Dr. Bobby Ezhuthachan
5. Dr. Subrat Kumar Das
6. Mr. Sanjoy Datta

7. Dr. Chetan Gowdigere
8. Mr. Santosh Kumar Singh
9. Mr. Akhilesh
10. Mr. M. C. Kumar
11. Mr. Shailesh G. Kulkarni
12. Dr. Sumedha
13. Dr. Yoshinori Matsuo
14. Dr. Shinji Shimasaki
15. Dr. Prabhu R.

Visiting Scientists

1. Dr. Harvinder Kaur Jassal
2. Dr. Andreas Nyffeler
3. Dr. Sushan Konar
4. Dr. Kirtiman Ghosh

Visiting Professor

1. Prof. Satya Deo

Administrative Staff

1.	Mr. P. B. Chakraborty	Registrar
2.	Mr. Raaj Kumar Gulati	Accounts Officer
3.	Dr. Vijay Raghav Tiwari	Librarian
4.	Mr. Manish Sharma	Scientific Officer C
5.	Mr. Amit Roy	Internal Audit and Administrative Officer
6.	Mr. Sanjai Verma	Systems Manager
7.	Mr. Prabhat Kumar	Senior Private Secretary
8.	Mr. K. S. Shukla	Professional Assistant
9.	Mr. A. K. Srivastava	Jr. Engineer (Electrical)
10.	Mr. V. K. Srivastava	Jr. Engineer (Civil)
11.	Mr. Jagannath Yadav	Accountant
12.	Mr. R. P. Sharma	Manager Guest House
13.	Ms. Archana Tandon	Office Superintendent
14.	Mr. Babu P. S.	Store Purchase Officer
15.	Ms. Anju Verma	Scientific Assistant
16.	Mr. U. K. Dwivedi	Cashier
17.	Mr. D. Malhotra	Upper Division Clerk
18.	Mr. K. K. Srivastava	Upper Division Clerk
19.	Mr. Yashpal Singh	Stenographer
20.	Ms. Sumitra	Upper Division Clerk
21.	Mr. P. N. Mishra	Jr. Library Assistant
22.	Mr. D. P. Sharma	Jr. Library Assistant
23.	Ms. Seema Agarwal	Receptionist
24.	Mr. Kashi Prasad	Driver
25.	Mr. D. N. Dubey	Bearer (Canteen Cadre)
26.	Mr. Lalloo Ram	Bearer (Canteen Cadre)
27.	Mr. Kamlesh Thakur	Bearer (Canteen Cadre)
28.	Mr. R. K. Dixit	Peon

29.	Mr. Kamta Prasad	Peon
30.	Mr. Rajesh Kumar	Sweeper
31.	Mr. Munna Lal	Gardener

Academic Report — Mathematics

Sukumar Das Adhikari

Work has been continued in some problems related to weighted generalizations of some combinatorial group invariants.

Publications:

1. Sukumar Das Adhikari, Sanoli Gun and Purusottam Rath, *Remarks on some zero-sum theorems,* Proc. Indian Acad. Sci. (Math. Sci.) **119, No. 3**, 275–281, (2009).
2. Sukumar Das Adhikari and Andrew Granville, *Visibility in the plane,* J. Number Theory **129, Issue 10**, 2227–2646, (2009).
3. Sukumar Das Adhikari, A. A. Ambily and B. Sury, *Zero-sum problems with subgroup weights,* Proc. Indian Acad. Sci. (Math. Sci.), **to appear**.

Conference/Workshops Attended:

1. *Analytical and additive activities*, Lille, France, June, 2009.
2. *International Conference and the Instructional School in Number Theory, PDE and Geometry*, Calicut, August, 2009.
3. *International Conference on Analytic Number Theory*, TIFR, Mumbai, October, 2009.
4. *Mathematics Phobia: Its genesis and remedies*, Santiniketan, February, 2010.

Visits to other Institutes:

1. Institut des Hautes Études Scientifiques (IHES), Bures-sur-Yvette, France, April, 2009.
2. Mathematical Institute of the Slovak Academy of Sciences, Bratislava, Slovakia, June, 2009.
3. University of Lille, France, July, 2009.
4. Ramakrishna Mission Vivekananda University, Belur, July, 2009.
5. IMSc, Chennai, July, 2009.
6. Chennai Mathematical Institute, Chennai, August, 2009.
7. Department of Mathematics, University of Calicut, August, 2009.
8. Department of Mathematics, IISc, Bangalore, September, 2009.
9. Institut des Hautes Études Scientifiques (IHES), Bures-sur-Yvette, France, November, 2009.
10. Panjab University, Chandigarh, December, 2009.
11. Department of Mathematics, Visva-Bharati, Santiniketan, 12 February 2010.

Invited Lectures/Seminars:

1. *Davenport constant with weights: recent developments,* Groupe d'Etude sur les ProBlèmes Diophantiens, Institut de Mathématiques de Jusssieu, at Chevaleret, (Université Pierre et Marie Curie), University of Paris VI, Jussieu, Paris, April, 2009.
2. *Two classical zero-sum constants and their generalizations with weights*, Mathematics seminar, Mathematical Institute of Slovak Academy of Sciences, Bratislava, June, 2009.
3. *Weighted generalization of two classical group invariants*, Mathematics seminar, Ramakrishna Mission Vivekananda University, Belur, July, 2009.
4. *Weighted zero-sum problems: recent progress*, Mathematics seminar, IMSc, Chennai, July, 2009.
5. *Colours in the fields: A walk in the garden of Ramsey-type theorems*, Mathematics seminar, Chennai Mathematical Institute, Chennai, August, 2009.
6. *Additive Combinatorics*, International Conference and the Instructional School in Number Theory PDE and Geometry, University of Calicut, August, 2009.
7. *Weighted zero-sum problems: recent progress*, Mathematics seminar, IISC, Bangalore, September, 2009.
8. *Visibility of Lattice points*, International Conference on Analytic Number Theory, TIFR, Mumbai, October, 2009.
9. *Visibility of Lattice points*, Seminar of the laboratory Combinatoire et Optimisation, University of Paris VI, Jussieu, Paris, November, 2009.
10. *Lectures on elementary and combinatorial number theory*, ATML School, Panjab University, Chandigarh, December, 2009.
11. *Visibility of Lattice points*, Mathematics seminar, Panjab University, Chandigarh, January, 2009.
12. *Learning Mathematics and Education in general: some remarks*, Mathematics Phobia: Its genesis and remedies, A three-day National Seminar at the Centre for Mathematics Education, Dept. of Mathematics, Siksha Bhavana, Visva-Bharati, Santiniketan, February, 2010.

Other Activities:

1. Gave a series of lectues in Combinatorics in the summer programme in Mathematics held at HRI in June 09 (June 1-5).
2. Organized and lectured in 'Finite Fields and Coding' workshop at HRI from 2nd November 2009 to the 14th November 2009.
3. The proceedings of the international conferences on Number Theory and Cryptography (*Number Theory and Applications*, Hindustan Book Agency, New Delhi, 2009), had been edited jointly with B. Ramakrishnan.

Punita Batra

In a joint work with Volodymyr Mazorchuk, We obtained a general setup for the study of Whittaker modules, which includes, in particular, Lie algebras with triangular decomposition and simple Lie algebras of Cartan type. For Lie algebras with triangular decomposition a family of simple Whittaker modules were constructed and their annihilators were described.

Publications:

1. Punita Batra, Xiangqian Guo, Rencai Lu, Kaiming Zhao, *Highest weight modules over pre-exp-polynomial Lie algebras,* Journal of Algebra, **322**, 12(2009), 4163-4180.
2. Tanusree Pal, Punita Batra, *Representations of graded multiloop Lie algebras,* Communications in Algebra, **38**, 1(2010), 49-67.

Preprints:

1. Punita Batra, Volodymyr Mazorchuk, *Blocks and Modules for Whittaker pairs,* submitted for publication.

Conference/Workshops Attended:

1. *2009 Winter meeting of the Canadian Mathematical Society,* Windsor, Ontario Canada, December 5-7, 2009.
2. *Platinum Jubilee* 75^{th} *Annual Conference of Indian Mathematical Society,* Kalasalingam University, Tamilnadu, December 27-30, 2009.
3. *International Conference on Algebra and its Applications,* Aligarh Muslim University, Aligarh, February 20, 2010.

Visits to other Institutes:

1. TIFR Mumbai, August 17-25, 2009.
2. Department of Mathematics, Uppsala University, Sweden, September 21-October 3, 2009.

Invited Lectures/Seminars:

1. Gave a Mathematics seminar in the *"Algebra and Geometry seminar"* at Uppsala University, Sweden; September 29, 2009.
2. Gave an invited talk *"Classification of Integrable representations for twisted toroidal Lie algebras"* in the "Lie Algebras and Representation Theory" session in 2009 Winter meeting of the Canadian Mathematical Society, Windsor, Canada; December 7, 2009.

3. Gave an invited talk *"Highest weight representations of pre-exp-polynomial Lie algebras"* in the IMS Conference, Kalasalingam Universiry, Tamilnadu; December 2009.
4. Gave an invited talk *"Highest weight representations of pre-exp-polynomial Lie algebras"* in the International Conference on Algebra and its Applications, Aligarh Muslim University, Aligarh; February 20, 2010.

Other Activities:

1. Gave six lectures on "Galois Theory" in Summer Programme in Mathematics(SPIM) at HRI in June, 2009.
2. Gave two lectures in the Rajbhasha scientific workshop at HRI in May, 2009.
3. Gave a Mathematics Seminar at the Centre of Behavioural and Cognitive Sciences, University of Allahabad, August 2009.
4. Taught a first year graduate course Algebra-II at HRI during January-May 2010.
5. Convener of Mathematics Visitor's Committee of HRI. Also serving as a member in the Rajbhasha Committee, the Office and Furniture Committee and the SYM(Special Years in Mathematics) Committee.

Kalyan Chakraborty

Studying various interesting special functions. In particular trying to develop a foundation of the theory of gamma function through the digamma function.

Working on the reduced length of a polynomial with complex coefficiants and its relation with Mahler measure.

Publications:

1. Kalyan Chakraborty and Florian luca, *Perfect powers in solutions to Pell equations,* Revista Columbiana de Mathematicas **43**, 71–86, (2009)
2. K. Chakraborty, S. Kanemitsu and T. Kuzumaki, *Finite expressions for higher derivatives of the Dirichlet L-function and the Deninger R-function,* Hardy-Ramanujan Journal **32**, 38–53, (2009)
3. K. Chakraborty, S. Kanemitsu, J. -H. Li and X. -H. Wang, *Manifestations of the Parseval identity ,* Proc. Japan Acad.**85**, 149–155, (2009)
4. K. Chakraborty, S. Kanemitsu and H. -L. Li, *On the values of a class of Dirichlet series at rational arguments,* Proc. Amer. Math. Soc. **138**, 1223–1230, (2010)
5. K. Chakraborty, S. Kanemitsu, H. Kumagi and Y. Kubara, *Shapes of objects and the golden ration,* Journal of Sangluo Univ. **23**, 18–27, (2009)
6. Kalyan chakraborty, Shigeru Kanemitsu and Haruo Tsukada, *Vistas of special function II,* World Scientific (2010)

Preprints:

1. K. Chakraborty, S. Kanemitsu and H. Tsukada, *Arithmetical Fourier series and the modular relation* (in prepaparation)
2. Kalyan chakraborty, *On the Chowla-Selberg integral formula for non-holomorphic Eisenstein series* (in preparation)
3. K. Chakraborty, S. Kanemitsu and X. -H. Wang, *The modular relation and the digamma function* (in preparation)

Conference/Workshops Attended:

1. *International Two Day Coference in Number Theory*, Japan, July, 2009.
2. *National School in Number Theory and Cryptography*, Nepal, December, 2009.
3. *National Seminar on Emerging Areas in Mathematics and applications*, India, January, 2010.
4. *National Symposium in Mathematics*, India, February 2010,

Visits to other Institutes:

1. Kathmandu niversity, Kathmandu, Nepal, December 2009,
2. Kinki University, Iizuka, Japan, July 2009,

3. Burdwan University, Burdwan, India, January 2010,
4. IIT Gandhinagar, Gandhinagar, India, February 2010.

Invited Lectures/Seminars:

1. *Lectures on basic Number Theory and cryptography*, National School on Number Theory and Cryptography, Kathmandu University, Dulikhel, December 2009.
2. *Finite expression of the derivative of the Dirichlet L-function and the deninger r-function*, International Conference in Number Theory, Kinki University, Iizuka, July 2009.
3. *Divisibility of the class numbers of real quadratic fields*, National Seminar on Emerging Areas in Mathematics and Applications, Burdwan University, Burdwan, January 2010.
4. *Class numbers with many prime factors*, National Symposium in Mathematics, IIT Gandhinagar, Gandhinagar, February 2010.

Other Activities:

1. Local Co-Ordinator of the various NBHM Tests, 2009–2010.

Chandan Singh Dalawat

Let K be a finite extension of $\mathbf{Q}_p$ or of $\mathbf{F}_p(\!(\pi)\!)$, where p is a prime number and π is transcendental, and let $M|K$ be the maximal abelian extension of exponent dividing p. The profinite group $G = \mathrm{Gal}(M|K)$ carries the ramification filtration $(G^u)_{u\in[-1,+\infty[}$ in the upper numbering.

In the characteristic-p case, the $\mathbf{F}_p$-space $K/\wp(K)$, where $\wp$ is the endomorphism $x \mapsto x^p - x$ of the additive group K, carries a natural filtration $(\overline{\mathbf{p}^n})_{n\in\mathbf{Z}}$, induced by the filtration of K by the powers $\mathbf{p}^n$ of the unique maximal ideal $\mathbf{p}$ of the ring of integers $\mathbf{o}$ of K ; we have $\overline{\mathbf{p}^n} = 0$ for $n > 0$. It was shown that this filtration is orthogonal to the ramification filtration under the Artin-Schreier pairing $G \times K/\wp(K) \to \mathbf{F}_p$. More precisely, we have the "orthogonality relation" $(G^u)^\perp = \overline{\mathbf{p}^{-\lceil u\rceil+1}}$ for real $u > 0$. In particular, the unramified degree-p extension of K corresponds to the line $\overline{\mathbf{p}^0} = \overline{\mathbf{o}} = \mathbf{F}_p$ in $K/\wp(K)$. (arXiv:0909.2541)

The analogue for $K|\mathbf{Q}_p$ containing a primitive p-th root ζ of 1 — discovered earlier — says that, under the Kummer pairing $G \times K^\times/K^{\times p} \to {}_p\mu$, we have the orthogonality relation $(G^u)^\perp = \bar{U}_{pe_1-\lceil u\rceil+1}$ for real $u > 0$, where units U_n of various levels $n \in \mathbf{Z}$ (with the convention that $U_n = K^\times$ for $n \in -\mathbf{N}$) provide the filtration $(\bar{U}_n)_{n\in\mathbf{Z}}$ on $K^\times/K^{\times p}$ (with $\bar{U}_{pe_1+1} = \{1\}$), and e_1 is the ramification index of $K|\mathbf{Q}_p(\zeta)$.

Now suppose that $K|\mathbf{Q}_p$ does not contain ζ. It is still possible to determine the ramification filtration on the finite group G by identifying the subspace in $K(\zeta)^\times/K(\zeta)^{\times p}$ corresponding to the extension $M(\zeta)|K(\zeta)$; it turns out to be the χ-eignespace, where $\chi : \mathrm{Gal}(K(\zeta)|K) \to \mathbf{F}_p^\times$ is the cyclotomic character giving the action on the p-th roots of 1. (arXiv:0912.2829)

Thus, for every finite extension K of $\mathbf{Q}_p$ or of $\mathbf{F}_p(\!(\pi)\!)$, the ramification filtration on $M|K$ can be determined without recourse to local class field theory. Combining the two approaches allows us to determine the norm group of the the maximal abelian exponent-p extension with ramification breaks in $[-1, n]$ for every $n \in \mathbf{N}$.

Three different notions of p-primary units in $\mathbf{Q}(\zeta)$ were compared and shown to be equivalent globally but not locally at $(1-\zeta)\mathbf{Z}[\zeta]$. This allows us to reconcile different formulations of Kummer's lemma in the literature, and to separate the local arguments (which hold for all p) from the global ones (which require p to be regular). (arXiv:0911.2566)

Publications:

1. Chandan Singh Dalawat, *Local discriminants, kummerian extensions, and elliptic curves,* Journal of the Ramanujan Mathematical Society **25** 1, 25–80, (2010)

2. Chandan Singh Dalawat, *Congruent numbers, elliptic curves, and the passage from the local to the global*, Resonance **14** 12, 1183–1205 (2009). [This paper was also listed in 2006–7, but the publication for which it was destined never appeared.]
3. J. Coates, C. S. Dalawat, A. Saikia and R. Sujatha (editors) *Guwahati workshop on Iwasawa theory of totally real fields*, 185 pp., Ramanujan Mathematical Society Lecture Notes (2010)

Preprints:

1. Chandan Singh Dalawat, *Further remarks on local discriminants*, arXiv:0909.2541. [Augmented version of the preprint listed last year.]
2. Chandan Singh Dalawat, *Primary units in cyclotomic fields*, arXiv:0911.2566.
3. Chandan Singh Dalawat, *Final remarks on local discriminants*, arXiv:0912.2829.

Conference/Workshops Attended:

1. *Arbeitstagung*, Bonn, 5–12 June 2009.
2. *Algebraische Zahlentheorie*, Oberwolfach, 21–27 June 2009.

Visits to other Institutes:

1. Universität Regensburg, Germany, May–June 2009.
2. Universität Heidelberg, Germany, 17–21 June 2009.
3. IISER, Poona, India, 27 July – 1 August 2009.

Invited Lectures/Seminars:

1. *Der Wilsonsche Satz*, Kolloquium, Universität Regensburg, 7 May 2009.
2. *Die Verzweigungsfiltrierung*, Universität Regensburg, 22 May 2009, Universität Heidelberg, 19 June 2009.
3. *From the local to the global*, Summer Workshop in Mathematics, IISER, Poona, 27 July–1 August 2009.

Other Activities:

1. Served as the doctoral examiner for a student at TIFR, Bombay.
2. Refereed some papers for international journals.
3. Interviewed candidates for the Kishore Vaigyanik Protashana Yojana.

Rukmini Dey

I worked out the geometric prequantization of non-abelian vortices. I also studied the coadjoint orbit representation of many integrable systems with the aim of quantizing them using the Kirillov method. I also studied some PT-symmetric quantum mechanical systems with the aim of quantizing them by defining a C-operator.

I studied multi-transonicity in black hole accretion–a study using generalized Strum chains.

I am trying to understand bifurcations in configurations of minimal surfaces (when wire frames are dipped in soap solutions) using catastrophe theory.

Publications:

1. Rukmini Dey, *Erratum: Geometric prequantization of the moduli space of the vortex equations on a Riemann surface,* Journal of Mathematical Phys. **50**, 119901, (2009)

Preprints:

1. Shilpi Agarwal, Tapas Das, Rukmini Dey, *Multi-transonicity in blackhole accretion–a mathematical study using generalized Strum chains,* (submitted)
2. Rukmini Dey, Samir K. Paul, *Quillen bundle and Geometric Prequantization of Non-Abelian Vortices on a Riemann surface,* (submitted)
3. Rukmini Dey, Samir K. Paul, *Geometric prequantization of various moduli spaces,* (submitted)

Visits to other Institutes:

1. C.T.Q.M., Aarhus University, Denmark, March-April,2009.
2. S.N. Bose Center, Kolkata , India, May-June, 2009.

Invited Lectures/Seminars:

1. *Geometric Prequantization of Various Moduli spaces*, Topology Seminar, C.T.Q.M., Aarhus University, Denmark, April, 2009.

Other Activities:

1. Conducting Adult Literacy classes for horticultural workers in Campus, beginning August, till now.
2. Attending Committee meetings.

Raghavendra Nyshadham

I have been working with my students on some problems of real algebraic geometry, involving semistable vector bundles over real abelian varieties, and also real parabolic vector bundles.

Other Activities:

1. Taught a second year graduate course, *Riemann Surfaces*, in the second semester of 2009–2010.
2. Taught a first year graduate course, *Algebra I*, in the first semester of 2010–2011.
3. Gave 10 lectures on *Differential Calculus* in SPIM 2009.
4. Organized the Mathematics Talent Search Test 2009.

D. Surya Ramana

We continue to study applications of a number of themes from the book Arithmetical aspects of the large sieve inequality by O. Ramaré (with the collaboration of D. S. Ramana), Harish-Chandra Research Institute Lecture Notes, 1. Hindustan Book Agency, New Delhi, 2009. For instance, in work in progress with O. Ramaré, we hope to use a method of Ramaré and Ruzsa, which relies in part on results in the aforementioned book, to improve upon the best upper bound known for $u(k)$, which is the smallest natural number such that every natural number can be expressed as the sum of $u(K)$ prime numbers all of the same colour, if the prime numbers are given K colours.

In the pre-print below, we give a simple proof of the main properties of the Selberg-Buerling functions, which have a number of applications in analytic number theory including the large sieve inequality.

Publications:

1. D.S. Ramana, *Arcs with no more than three integer points on conics,* Acta Arithmetica, to appear.
2. J. Cilleruelo, D.S. Ramana and O. Ramaré, *Number of Rational Numbers Determined by Large Sets of Integers,* Bulletin London Math. Soc. **42**, 517-526, (2010)

Preprints:

1. D.S. Ramana, *A Remark on the Beurling-Selberg Function*, submitted.

Conference/Workshops Attended:

1. *Workshop on Analytic Number Theory*, Chennai, Feb-March, 2010.

Other Activities:

1. Co-oridinated the workshop on Analytic Number Theory mentioned above.
2. Lectured in the ATM programme for College Lecturers in Number Theory, P.U. , Chandigrah, Dec. 2009.
3. Guided two students for their seminars (HRI course work) in the Jan-May semester and one student in the August-December semester.

B. Ramakrishnan

1. **The Theta-operator and the Divisors of Modular Forms** (with Sanoli Gun): This work is the revised version of our paper titled "Divisors of modular forms", described in the last year's annual report.

2. **A canonical subspace of modular forms of half-integral weight** (with Sanoli Gun and M. Manickam): This work is the revised version of our paper titled "A characterization of the space of new forms of half-integral weight and a conjecture of Zagier", described in the 2006-07 annual report. In this work we characterise the space of newforms of weight $k + 1/2$ on $\Gamma_0(4N)$, N odd and square-free (studied by Manickam, Ramakrishnan and Vasudevan) under the Atkin-Lehner $W(4)$ operator. As an application, we show that the (± 1)-eigensubspaces of the $W(4)$ operator on the space of modular forms of weight $k + 1/2$ on $\Gamma_0(4N)$ is mapped to modular forms of weight $2k$ on $\Gamma_0(N)$, under a class of Shimura maps. The existence of such subspaces having this mapping property was conjectured by Zagier in a private communication. One of the special features of the (± 1) -eigensubspaces is that the $(2k + 1)$-th power of the classical theta series of weight $1/2$ belongs to the $+$ eigensubspace and hence this gives interesting congruences for $r_{2k+1}(p^2)$.

Publications:

1. B. Ramakrishnan and Brundaban Sahu, *Rankin's Method and Jacobi Forms of Several Variables,* J. Aust. Math. Soc. **88** (2010), 131–143 doi:10.1017/S1446788709000330

Preprints:

1. S. Gun and B. Ramakrishnan, *The Theta-operator and the Divisors of Modular Forms,* Submitted.
2. S. Gun M. Manickam and B. Ramakrishnan, *A canonical subspace of modular forms of half-integral weight,* (accepted for publication in Math. Ann.)

Conference/Workshops Attended:

1. Instructional School on Number Theory, PDE and Geometry, University of Calicut, Calicut, August, 2009.
2. International Conference on Number Theory, PDE and Geometry, University of Calicut, Calicut, August, 2009.
3. Workshop on the theory Of Jacobi forms and Siegel modular forms, The Institute of Mathematical Sciences and Vivekananda College, Chennai, Nov-Dec, 2009.
4. 20th Annual conference of Jammu Mathematical society, University of Jammu, Jammu, February, 2010.

5. 24th Automorphic Forms Workshop, Honolulu, Hawaii, USA, March, 2010.

Visits to other Institutes:

1. The Institute of Mathematical sciences, Chennai, December, 2009.

Invited Lectures/Seminars:

1. *Sums of squares*, Instructional School on Number Theory, PDE and Geometry, Calicut, August 2009.
2. *Representation of integers as sums of an odd number of squares*, International Conference on Number Theory, PDE and Geometry, Calicut, August 2009.
3. *A characterization of the space of new forms of half-integral weight*, ICTS, Analytic Number Theory 2009, TIFR, Mumbai, October 2009.
4. *Modular forms of half-integral weight*, Workshop on the theory Of Jacobi forms and Siegel modular forms, Chennai, Nov-Dec 2009.
5. *Theta series and sums of squares*, 20th Annual conference of Jammu Mathematical Society, Jammu, Feb 2010.
6. *An upper bound for the mean square of twisted L-functions of half integral weight*, 24th Automorphic Forms Workshop, Hawaii, USA, March 2010.

Other Activities:

1. Supervising three students for their PhD. One of the students (Mr. Soumya Das) will be submitting his thesis in April 2010.
2. Member of the Board of Studies of HBNI for Mathematical Sciences.
3. Resident faculty at the MTTS programme held at RIE, Mysore and gave a course on "Algebra" for Level 1 participants during May-June, 2009.
4. Organized the lecture series on "An Introduction to Siegel Modular Forms" by Professor W. Kohnen during December 2009 (under the SYM project).
5. Advisory committee member of the UGC-SAP DRS-1 programme (Mathematics) of the Lucknow University.
6. Member of the National Library Committee of NBHM (North Central Zone)

Ratnakumar Peetta Kandy

I have been continuing my work on Schrödinger equations associated to the Hermite, special Hermite and other operators of interest in Harmonic analysis. A crucial step in establishing the existence of solutions for the associated nonlinear Schrödinger equation is the embedding problem for the Sobolev spaces associated with these differential operators in suitable L^p spaces. In a joint work with my Ph. D. student Vijay Sohani, we have been able to establish an embedding result for Sobolev spaces associated to the Hermite and Special Hermite operators. We are also working on establishing some interesting characterisation of these Sobolev spaces.

Another work that I have been involved in, concerns with a qualitative uncertainty principle on nilpotent lie groups. In a joint work with E.K. Narayanan, we proved a Benedick's type theorem for two step nilpotent Lie groups. This extends and improves our recent result on the Heisenberg group, appeared in the Proceedings of the American Mathematical Society.

Publications:

1. E.K. Narayanan and Ratnakumar P.K. *Benedick's Theorem for the Heisenberg group,* Proc. of Amer. Math. Soc **138**, 2135-2140, (2010)

Preprints:

1. E.K. Narayanan and Ratnakumar P.K., *A qualitative uncertainty principle on two step nilpotent Lie groups,*

Conference/Workshops Attended:

1. *Discussion Meeting on Harmonic Analysis*, Niser, Bhubaneswar, India, January, 2010,

Visits to other Institutes:

1. Indian Institute of Science, Bangalore, India, November 2009,
2. NISER, Bhubaneswar, India, January 2010.

Other Activities:

1. Organised Discussion Meeting on Geometry and Analysis, HRI, Allahabad, 19th Jan - 2nd Feb 2010, (Jointly with Rukmini Dey).
2. Organised the Summer Programme in Mathematics (SPIM) at HRI, Allahabad, 1st - 19th June, 2009, (Jointly with Kalyan Chakraborty).
3. Gave a set of four lectures on Weyl Quantisation, in the Discussion Meeting on Geometry and Analysis organised at HRI.

4. Gave two lectures on non-linear Schrödinger equations, in the above Discussion Meeting on Geometry and Analysis.
5. Gave a set of eight lectures on Measure Theory in SPIM 2009, at HRI.
6. Taught the course "Topology II" for third semester Ph. D. Students at HRI, in 2010.
7. Served in the sports and entertainment committee

Ravindranathan Thangadurai

We proved that for all large enough integers n, the elements of any subgroup H (with $|H| > \sqrt{n}$) of the unit group of $G := \mathbf{Z}/n\mathbf{Z}$ uniformly spread out among the elements of G. For this, we need to study the Bernoulli polynomials with character χ on G/H and estimate the Dirichlet' L-functions. This result was obtained while studying the digits of $1/p$ for any prime p. Also, in another work, it was proved that the least prime $p \equiv 1 \pmod{n}$ is bounded by $(2^n - 1)/7$ for all composite integers $n > 7$.

Publications:

1. R. Balasubramanian, S. Laishram, T. N. Shorey and R. Thangadurai, *The number of prime divisors of the product of consecutive integers*, Journal of Combinatorics and Number Theory, **1 (3), 65-73, (2009)**.
2. F. Luca and R. Thangadurai, *On an arithmetic function considered by Pillai*, Journal de theorie des nombres de Bordeaux **21 (3), 693-699, (2009).**

Preprints:

1. W. D. Gao, M. N. Chintamani, B. Moriya, P. Paul and R. Thangadurai, *On Davenport's Constant.* Preprint, (2009).
2. R. Thangadurai, *Remark on a paper "Primitve roots satisfying a coprime condition"*, Preprint , (2010).
3. M. Ram Murty, and R. Thangadurai, *The class number of* $\mathbf{Q}((-p)^{1/2})$ *and digits of* $1/p$, Preprint, (2010).
4. R. Thangadurai, *The least prime p congruent to* 1 *modulo* n, To appear in: American Mathematical Monthly.
5. R. Balasubramanian, F. Luca and R. Thangadurai, *On the exact degree of* $\mathbf{Q}(\sqrt{a_1}, \cdots, \sqrt{a_\ell})$ *over* $\mathbf{Q}$, To appear in: Proc. Amer. Math. Soc..

Conference/Workshops Attended:

1. *International Conference on Additive and Analytical Number Theory*, Lille, France, July, 2009.
2. *Journees Arithmetiques*, St-Etienne, France, July, 2009.
3. *International conference in Number Theory, PDE and Geometry*, Calicut, August, 2009.
4. *International conference on "Analytic Number Theory"*, Mumbai, October, 2009.
5. *AIS on Analytic Number Theory*, Chennai, February, 2010.

Visits to other Institutes:

1. Institute of Mathematical Sciences, Chennai, April and December - January, 2010
2. Chennai Mathematical Institute, Chennai, December, 2009.
3. Bhaskaracharya Pradisthana, Pune, December, 2009.

Invited Lectures/Seminars:

1. *A popular lecture on Research in Mathematics*, Government College of Arts and Science, Rasipuram, Salem, April, 2009.
2. *S. S. Pillai's new proof of Betrand's Postulate*, S. P. College, Pune, December, 2009.
3. *A least prime* $p \equiv 1 \pmod{n}$, Vivekananda College, Chennai, January, 2010.

Other Activities:

1. CSIR - Net Evaluation Meeting, August, 2009.
2. Completed the Collected works of S. S. Pillai which is to be published by RMS- Lecture notes series.

Manoj Kumar

Let $1 \to N \to G \xrightarrow{\pi} H \to 1$ be a short exact sequence of groups, i.e., an extension of a group N by the group $H \simeq G/N$. If N is abelian, then such an extension is called an *abelian extension*. I (jointly with Mahender Singh and I. B. S. Passi) constructed certain exact sequences and applied them to study extensions and liftings of automorphisms in abelian extensions. More precisely, we studied, for abelian extensions, the following well-known problem:

Problem. *Let N be a normal subgroup of G. Under what conditions (i) can an automorphism of N be extended to an automorphism of G; (ii) an automorphism of G/N is induced by an automorphism of G?*

Regarding lifting of automorphisms we proved: Let N be an abelian normal subgroup of a finite group G. Then the following hold: (i) An automorphism ϕ of G/N lifts to an automorphism of G centralizing N provided the restriction of ϕ to some Sylow p-subgroup P/N of G/N, for each prime number p dividing $|G/N|$, lifts to an automorphism of P centralizing N. (ii) If an automorphism ϕ of G/N lifts to an automorphism of G centralizing N, then the restriction of ϕ to a characteristic subgroup P/N of G/N lifts to an automorphism of P centralizing N.

Regarding extension of automorphisms we proved: Let N be an abelian normal subgroup of a finite group G. Then an automorphism θ of N extends to an automorphism of G centralizing G/N if, and only if, for some Sylow p-subgroup P/N of G/N, for each prime number p dividing $|G/N|$, θ extends to an automorphism of P centralizing P/N.

(ii) Let G be a group. An automorphism α of G is called class preserving if $\alpha(x)$ lies in the conjugacy class of x for all $x \in G$. I (jointly with V. Bardakov and A. Vesnin, both from Russia) studied class preserving automorphisms of $n \times n$ uni-triangular matrix group M over an arbitrary field $\mathcal{F}$. We proved that all class preserving automorphisms of such groups M are inner if and only if the underlined field $\mathcal{F}$ is a prime field. We also studied class preserving automorphisms of $H = M/\gamma_3(M)$ in the case when the underlined field $\mathcal{F}$ is finite. We studied the structure and the order of the group of all class preserving automorphisms of H.

(iii) Let G be a group. An element x of G is called small if either x belongs to the center of G or the size (length) of the conjugacy class of x is smallest among all conjugacy classes in G lying outside the center of G. Let $M(G)$ denote the subgroup of G generated by all small elements of G. I have been working on the problem of bounding the nilpotency class of G, when G is a finite solvable group.

(iv) An automorphism β of a group G is called central if it induces identity on $G/Z(G)$, where $Z(G)$ denotes the center of G. I (jointly with Vivek Kumar Jain) have been studying finite p-groups G, p an odd prime, whose all automorphisms are central. One can notice that such groups must be of nilpo-

tency class 2. There are several examples of p-groups G such that the group of all automorphisms of G is abelian (and hence all automorphisms are central). But all of these groups are special (a group is said to be special if its center, commutator subgroup and the Frattini subgroup coincide). Moreover, there is a published conjecture which claims that such groups must be special. We are in the process of constructing counter examples to this conjecture. We are also in the process of constructing examples of finite p-groups G such that all automorphisms of G are central, the group of all these automorphisms is non-ableian and G does not have a non-trivial abelian direct factor. Such groups are not known in the literature and asking for construction of such groups is a published problem.

Publications:

1. Manoj K. Yadav, *On central automorphisms fixing the center element-wise,* Comm. Algebra **37**, 4325-4331, (2009)

Preprints:

1. I. B. S. Passi, Mahender Singh and Manoj K. Yadav, *Automorphisms of abelian group extensions,* Accepted for publication in J. Algebra.
2. V. Bardakov, A. Vesnin and Manoj K. Yadav, *Conjugacy class preserving automorphisms of nilpotent groups,* (in preparation).
3. Manoj K. Yadav, *On subgroups generated by small classes in finite groups,* (in preparation).
4. Vivek Kumar Jain and Manoj K. Yadav, *On finite p-groups whose all automorphisms are central,* (in preparation).

Conference/Workshops Attended:

1. *International Conference on Character Theory of Finite Groups (Isaacs - 09)*, Spain, June 2009.
2. *International conference Groups St. Andrews 2009*, U. K., August 2009.
3. *Recent Trends in Algebra and Algebraic Number Theory*, India, November 2009.
4. *International Conference on Algebra and Its Applications*, India, February 2010.

Visits to other Institutes:

1. Steklov Mathematical Institute, Moscow, Russia, June 2009.
2. Sobolev Institute of Mathematics, Novosibirsk, Russia, June 2009.

Invited Lectures/Seminars:

1. *Automorphisms of finite p-groups*, Sobolev Institute of Mathematics, Novosibirsk, Russia, June 2009.
2. *Class preserving automorphisms of finite p-groups: A survey*, International conference Groups St. Andrews 2009, University of Bath, UK, August 2009.
3. *Automorphisms of abelian group extensions*, Recent Trends in Algebra and Algebraic Number Theory, Dept. of Mathematics, Panjab University, Chandigarh, November 2009.
4. *Central automorphisms of finite p-groups*, International Conference on Algebra and Its Applications, Dept. of Mathematics, Aligarh Muslim University, Aligarh, February 2010.

Academic recognition/Awards:

- Indian National Science Academy medal for young scientists, 2009.

Other Activities:

1. Gave two lectures in Rajbhasha programme, May 2009.
2. I was a member of various committees constituted in HRI, 2009 - 2010.

Satya Deo

One area of my present interest has been to work on topological methods in combinatorial mathematics in general. In fact a research project entitled "Topological Methods in combinatorial Mathematics" has been sanctioned by the DST, Govt of India, to me as PI and Prof S.D.Adhikari as Co-PI. We have already started working on this project by going through the works of various other authors like A. Bjorner, Alon and Lovasz, who have already done some remarkable work using the famous Borsuk-Ulam theorem of algebraic topology. Further work on the project is in progress.

During this academic year 2009-2010, I have continued to work on some additional problems on nonmetrizable manifolds besides determining the mapping class groups of such spaces. One problem on which I, with David Gauld, have concentrated most is a possible generalization of the "bagpipe theorem" of Peter Nyikos in dimension three. We have obtained some initial results which hopefully will mature in a final result soon.

Concerning the topic on cohomological dimension, it has been proved by Dranishnikov that the cohomological dimension does not behave well with respect to Cech compactification. This is in contrast with the classical covering dimension. There is, however, an interesting positive result proved by L. Rubin which asserts that *if the space is finitistic, then the cohomological dimension of X and its Stone-Cech compactification βX are same*. We are investigating whether or not the converse of Rubin's theorem is also true. There seems to be some positive evidences for such a possibility.

Publications:

1. Mathieu Ballif, Satya Deo and David Gauld, *The mapping class group of powers of the long ray and other nonmetrizable spaces,* Topology and its Applications **157,(2010)1314-1324**
2. Satya Deo and V.V.Awasthi, *An Inverse Limit Systems of nonempty objects with empty limit.* Indian J. Math, **51 (2009)689-697.**

Preprints:

1. Satya Deo, *Cohomological dimension and finitistic spaces*, (in preparation)

Conference/Workshops Attended:

1. *75th Annual Conference of the Indian Mathematical Society*, Kalasalingam University, Krishnankoil, Viruddh Nagar, Tamil Nadu, Dec 27-30, 2009.
2. *97th Annual Session of the Indian Science Congress Association, Thiruanantpuram, Kerala. Jan 3-7, 2010*
3. *Annual Conference of the Society for History of Mathematics, University of Delhi, Jan 7-9, 2010*

4. *Annual conference of Jammu Mathematical Society, Jammu, during March 26-29, 2010.*

Visits to other Institutes:

1. Department of Mathematics, University of Auckland, New Zealand, May 10-19, 2009.
2. Department of Mathematics, R.D.University, Jabalpur, Sep 23-25, 2010.
3. Bhaskaracharya Pratisthan, Pune, June 8-15, 2009.

Invited Lectures/Seminars:

1. *Six lectures on Algebraic Topology*, AFS II, Bhaskaracharya Pratisthan, Pune, June 8-13, 2009.
2. *Five lectures on Fundamantal Groups, at SPIM, HRI, Allahabad, June 16-19, 2009*
3. *Two lectures on Riemann- Geometry and Topology, R.D.University, Jabalpur, Sep 2009.*
4. *One lecture on Cohopficity of three-manifolds, HRI Faculty presentations during the session 2009-10.*

Academic recognition/Awards:

- Awarded Gold Medal by the Prime Minister of India as M.K.Singal Award of the Indian Science Congress at the 97th Session held at Thiruvananthpuram, Kerala.
- Continued to work as the Academic Secretary of the Indian Mathematical Society during the year 09-10 and elected academic secretary for a term of another three years (2010-2012).
- Elected Sectional President of Mathematics including Statistics, Indian Science Congress, 2010-2011.
- Delivered the keynote address during the inaugural session of the Jammu Mathematical Society, March 26-29, 2010.

Other Activities:

1. One student completed his PhD work at HRI, Allahabad, under my supervision (indirect).
2. As the Academic Secretary, I planned and organized the complete academic programme of the 75th annual conference of the Indian Mathematical Society held at the Kalasalingam University, Krishnankoil, Tamil Nadu Dec 27-30,2009.
3. Taught a course on Topology-I to the first year students of HRI during the first semester of the session 2009-10.

Sanjaykumar Hansraj Amrutiya

Let X be a smooth projective variety defined over a perfect field k of positive characteristic. We constructed the neutral Tannakian category of certain vector bundles over X which is a full subcategory of Nori-semistable vector bundles on X. By the Tannaka duality, there is an affine group scheme corresponding to this neutral Tannakian category which we called *the F–fundamental group scheme* of X. We proved that the F–fundamental group scheme respect the product but does not respect the base change. We studied the behavior of the F–fundamental group scheme under finite étale morphisms and also give the relation of the F–fundamental group scheme with the Nori's fundamental group scheme and the étale fundamental group over a finite field.

I have been also studying some problems related to vector bundles and real algebraic curve.

Publications:

1. S. Amrutiya and I. Biswas, *On the F-fundamental group scheme,* Bull. Sci. Math. (2009), doi:10.1016/j.bulsci.2009.12.002, in press.

Conference/Workshops Attended:

1. *Differential Geometric Methods in Algebraic Geometry*, TIFR, April 2009.

Other Activities:

1. Helped in organizing HRI Science talent test (Mathematics), 2009.

Mohan Namdev Chintamani

We continued our study of "Zero-Sum Problems", specially weighted versions of Davenport's constant and EGZ-constant. Consider a sequence S with length $n + r$, in $\mathbb{Z}/n\mathbb{Z}$ and the subset $A = (\mathbb{Z}/n\mathbb{Z})^*$. We investigated the number of A-weighted n-sums (subsequence sums of S) when 0 is not an A-weighted n-sum. In particular, for n a prime-power or an odd integer our result gives the EGZ-constant for above group. This is related to a result of F. Luca and S. Griffiths.

Other than above type of problems , I am also sutdying "Additive Combinatorics".

Preprints:

1. M. N. Chintamani, B. K. Moriya, P. Paul *The Number of Weighted n-Sums* Int. J. Mod. Math. **(to appear)**.
2. W. D. Gao, M. N. Chintamani, B. K. Moriya, P. Paul, And R. Thangadurai, *On Davenports Constant*.

Conference/Workshops Attended:

1. *Discussion Meeting on "Finite Fields and Coding Theory"* , Nov 2-14, 2009. HRI, India.

Jaban Meher

In a joint work with W.Kohnen we have studied some properties of exponents of q-product expansions of certain generalized modular functions on the Hecke congruence subgroup $\Gamma_0(N)$.

Publications:

1. W.Kohnen and J. Meher , *Some remarks on the q-exponents of generalized modular functions,* The Ramanujan Journal,(To appear).

Conference/Workshops Attended:

1. *SMS 2009,Automorphic forms and L-function:computational aspects*, Universite de Montreal,Montreal,Canada,22 June-3 July,2009.
2. *Workshop on Theory of Jacobi forms and Siegel modular forms*, RKM Vivekananda College and IMSc,Chennai,23 November-5 December,2009.

Other Activities:

1. Gave two lectures in Rajbhasha programme; May,2009.
2. Tutor for Algebra course taught in SPIM; June,2009.

Bhavin K. Moriya

I have been studying weighted zero sum problems. If G is a finite abelian group of rank n then one would like to determine a smallest integer t such that for a given sequence S of length t there exists a zero sum subsequence of length n. We have determined this number for the group of the form $(\mathbb{Z}/n\mathbb{Z})^r$ under certain assumptions. In particular, this result concludes the conjecture of Prof. Weidong Gao under certain assumptions. We have also been working on number of weighted n-sums of a sequence S over a group G, where the sequence S doesn't have a zero sum subsequence of length $n = |G|$ with respect to given weights. In a joint work with Mohan Chintamani and Prabal Paul, we have solved this problem for a group $G = \mathbb{Z}/n\mathbb{Z}$ with weights as set of units modulo n, where n is either a prime power or an odd number. In a joint work with R. Thangadurai, W. Gao, Mohan Chintamani, Prabal Paul, an upper bound on Davenport constant for a group $(\mathbb{Z}/n_1\mathbb{Z}) \oplus (\mathbb{Z}/n_2\mathbb{Z}) \oplus \cdots \oplus (\mathbb{Z}/n_r\mathbb{Z})$, where $1 < n_1|n_2|\cdots|n_r$, have been obtained.

Currently, I am reading additive combinatorics, zero sum problems and symbolic dynamics.

Preprints:

1. B. K. Moriya, *On Zero sum subsequences of restricted size,* Proc. Indian Acad. Sci. (Math. Sci.), to appear.
2. M. N. Chintamani, B. K. Moriya, P. Paul, *The number of weighted n-sums,* Int. J. Mod. Math., to appear.
3. M. N. Chintamani, W. D. Gao, B. K. Moriya, P. Paul, R. Thangadurai, *On Davenport's constant*.

Conference/Workshops Attended:

1. *Discussion meeting on Finite Fields and Coding Theory*, HRI, November 2-14, 2009.

Karam Deo Shankhadhar

M. Kaneko and M. Koike studied extremal quasimodular forms of depth 1 and partially in the case of depth 2, which are soloutions of certain differential equations. A natural question in this work is the existence of extremal quasimodular forms in higher depths satisfying certain differential equations. Work towards obtaining some results in this direction is in progress. I am working under the guidance of Prof. B. Ramakrishnan.

Apart from this I have been learning the theory of second order modular forms.

Conference/Workshops Attended:

1. *Workshop on Theory of Jacobi Forms and Siegel Modular Forms*, Vivekananda College and IMSc, Chennai, November - December, 2009.
2. *Lecture series given by Professor M. Waldschmidt on Transcendence*, CMI, Chennai, December, 2009.

Vijay Kumar Sohani

I am working under the guidance of Dr. P. K. Ratnakumar. My research project concerns the study of local existence of Schrodinger equations associated to Hermite and special Hermite operators in suitable Sobolev spaces, associated to these operators. A natural question in this connection is the embedding problem for these Sobolev spaces. We have been successful in obtaining such a embedding results, and I am continuing working on the above problem.

Conference/Workshops Attended:

1. *Workshop and a Centenary Conference on Analysis and its Applications*, IISc, Bangalore, May 14-23,2009 and May 25-27,2009.
2. *Workshop and Eleventh Discussion Meeting on Harmonic Analysis*,NISER, Bhubaneswar,December 28,2009-January 5,2010 and January 6-9,2010.
3. *Discussion Meeting on Analysis and Geometry*, HRI, Allahabad,January 20-February 02,2010.
4. *Workshop on Functional and Harmonic Analysis*,Kerala School of Mathematics, Kozhikode, February 01-10,2010.

Other Activities:

1. Tutor for *Analysis I* course during the period July-December 2009, HRI, Allahabad.
2. Tutor for *Measure Theory* course taught in Summer Programme in Mathematics (SPIM), HRI, Allahabad, June 2009.

Vivek Kumar Jain

Let $(G, .)$ be a group of order r. An ordered $r-$ tuple $(n_1, n_2, \ldots, n_r)$ in $\mathbb{N}^r$ such that $1 = n_1 < n_2 \leq \ldots \leq n_r$ is called *order structure* of G if the elements of G can be put in a sequence $\{x_1, x_2, \ldots, x_r\}$ of length r such that the order of x_i in G is n_i, $1 \leq i \leq r$. I determine all possible order structures for an odd order nilpotent group with class 2. I jointly with Dr. M. K. Yadav worked on odd prime power nilpotent group with class 2 and find a family of examples of non-special p-groups (p is an odd prime) whose automorphism group is abelian. These examples disprove the conjecture that odd prime power order groups with abelian automorphism group are special.

Publications:

1. Vivek Kumar Jain, *On odd order nilpotent group with class 2*, Arch. Math. **94**, 29-34, (2010)

Preprints:

1. Vivek Kumar Jain, *On the isomorphism classes of transversals-III*, (in preparation).
2. V. K. Jain, M. K. Yadav, *On finite p-group whose all automorphisms are central*, (in preparation).

Conference/Workshops Attended:

1. *Discussion Meeting on " Finite Fields and Coding Theory"*, HRI, Allahabad, India, November, 2009.

Invited Lectures/Seminars:

1. *Transversals in Groups*, Monthly Seminar, HRI, Allahabad, September 2009.
2. *On finite Nilpotent groups and JND-groups*, Monthly Seminar, HRI, Allahabad, September 2009.

Pavinder Singh

I have been working over the computation of Betti numbers of monomial ideals. We have computed the Betti numbers of a generalized permutohedron ideals. Now I am working over a problem on the generalized permutohedron ideals.

Publications:

1. C. Kumar and P. Singh, *Deficiently extremal Cohen-Macaulay algebras*, Proc. Indian Acad. Sci.(Math. Sci), **120**(2),2010.

Preprints:

1. C. Kumar, R. Jamwal and P. Singh, *Betti numbers of a Generalized Permutohedron ideals*,
2. C. Kumar, P. Singh and A. Kumar, *Counting formula for* 3×3 *generalized magic squares*,

Conference/Workshops Attended:

1. *Discussion meeting on Finite Fields and Coding Theory*, November 2009, HRI Allahabad.
2. *International School on Combinatorics*, January 2010, University of Sevilla, Spain.

Invited Lectures/Seminars:

1. *Nearly Extremal Cohen-Macaulay and Gorenstein algebras*, HRI Seminars and Colloquia, HRI Allahabad, December 2009.
2. *Deficiently Extremal Cohen-Macaulay algebras*, 20th Annual Conference of Jammu Mathematical Society, Department of Mathematics, Jammu University, Jammu, February 2010.

Other activities

1. Tutor in the *ATM Advanced Instructional School in Commutative Algebra*, 14 May-3 June, 2009 held at IIT Bombay funded by NBHM, DAE, Govt. of India.
2. Tutor in the Fifth *ATM Annual Foundation School* II, 8 June-4 July, 2009 held at Bhaskaracharya Pratishthana, Pune funded by NBHM, DAE, Govt. of India.

Academic Report — Physics

Jasjeet Singh Bagla

The cosmological principle is the bedrock on which models of the universe are constructed and studied. It states that the universe is homogeneous and isotropic at large scales. Fractal dimensions are often used to test the cosmological principle using the galaxy distribution, i.e., whether the distribution of galaxies at large scales is consistent with a homogeneity or not. In earlier work (Bagla, Yadav and Seshadri, 2008) we had shown that the Fractal dimensions can be related directly to the two point correlation function at scales where clustering is weak. We demonstrated that the finite number of galaxies and clustering both lead to deviations of the Fractal dimension from the spatial dimension.

We have recently generalized this correspondence to derive an expected error in Fractal dimensions from the expected errors in two point correlation function for a given survey. We show that it becomes possible to define an unambiguous scale of homogeneity where the deviation of the Fractal dimension from the spatial dimension equals the expected observational error in the Fractal dimension. The scale of homogeneity defined in this manner is close to 260 h^{-1}Mpc and is largely independent of epoch and the tracer used for estimating it (Yadav, Bagla and Khandai, 2010). Observational determinations often have additional sources of error that lead to an underestimation of the scale of homogeneity.

We have recently pointed out that the hyperfine transition of singly ionized Helium-3 can be used to observe the inter-galactic medium (IGM) at high redshifts. Given that neutral Hydrogen and singly ionized Helium do not coexist in most situations, such observations can be used to probe regions of the IGM that cannot be observed using the redshifted emission from the hyperfine transition of neutral Hydrogen. Observations of this type can also provide strong constraints on primordial nucleosynthesis in the early universe (Bagla and Loeb, 2009).

Using N-Body simulations and a few assumptions about distribution of neutral Hydrogen in the universe, we estimated time required to detect the redshifted emission from the hyperfine transition with a rest frame wavelength of 21 cm. We have shown that the redshift $z = 1.3$ is optimal for detection of the cosmological distribution of neutral Hydrogen by the GMRT. Statistical detection, as well as detection of rare peaks, is possible with a few hundred hours of observations with the GMRT (Bagla and Khandai, 2009; Khandai, Datta and Bagla, 2009).

It has been known for some time that local collapse of individual density peaks can be used to give an approximate description of growth of density perturbations in the universe. Indeed, the theory can be cast in terms where it is independent of the initial spectrum of fluctuations. Clearly, the approximate theory must break down at some level. We have given the first conclusive demonstration of the departure of mass functions from a universal form. This

has been done using a suite of N-Body simulations with power law spectrum for the initial spectrum of density fluctuations (Bagla, Khandai and Kulkarni, 2009).

Publications:

1. Bagla J. S., Prasad Jayanti and Khandai Nishikanta, *Effects of the size of cosmological N-Body simulations on physical quantities — III: Skewness*, MNRAS **395**, 918, (2009)
2. Bagla J. S. and Khandai Nishikanta, *The Adaptive TreePM: An Adaptive Resolution Code for Cosmological N-body Simulations*, MNRAS **396**, 2211 (2009)
3. Khandai Nishikanta and Bagla J. S., *A Modified TreePM Code*, Research in Astronomy and Astrophysics **9**, 861 (2009)
4. Bagla J. S., Kulkarni Girish and Padmanabhan T., *Metal Enrichment and Reionization Constraints on Early Star Formation*, MNRAS **397**, 971 (2009)

Preprints:

1. Bagla J. S. and Loeb A., *The hyperfine transition of ^{3}He II as a probe of the inter-galactic medium*, arxiv:0905.1698
2. Bagla J. S., Khandai Nishikanta and Kulkarni Girish, *Mass function of haloes: scale invariant models*, arxiv:0908.2702
3. Bagla J. S. and Khandai Nishikanta, *H I as a probe of the large scale structure in the post-reionization universe: Power Spectrum and its evolution*, arxiv:0908.3796
4. Khandai Nishikanta, Datta Kanan K. and Bagla J. S., *H I as a probe of the large scale structure in the post-reionization universe: Visibility correlations and prospects for detection*, arxiv:0908.3857
5. Yadav Jaswant, Bagla J. S. and Khandai Nishikanta, *Fractal dimensions as a measure of the scale of homogeneity*, arxiv:1001.0617

Conference/Workshops Attended:

1. *Gravitation and Astronomy : Frontiers in Theory and Observation*, India, August 2009.
2. *High Performance Computing in Observational Astronomy*, India, October 2009.
3. *IUCAA-Kashmir University Workshop on Advances in Astronomy and Astrophysics*, India, November 2009.
4. *Cosmological Reionization*, India, February 2010.
5. *National Symposium on Space Science*, India, February 2010.
6. *International Colloquium on Perspectives in Fundamental Research*, India, March 2010.

Visits to other Institutes:

1. TIFR, Mumbai, India, August 2009.
2. IISER, Chandigarh, India, Oct.-Nov. 2009.
3. TIFR, Mumbai, India, December 2009.

Invited Lectures/Seminars:

1. *Probing the universe with hyperfine transitions*, Gravitation and Astronomy : Frontiers in Theory and Observation, IUCAA, Pune, August 2009.
2. *Observing the early universe in Hyperfine transition of neutral Hydrogen*, Colloquium, Punjab University, Chandigarh, October 2009.
3. *Probing the high redshift universe with hyperfine transitions*, Institute Colloquium, TIFR, Mumbai, December 2009.
4. *Probing the high redshift universe with hyperfine transition of ^{3}He II*, Cosmological Reionization, HRI, Allahabad, February 2010.

Other Activities:

1. I organized an international conference on *Cosmological Reionization*. This was held at HRI from February 16-20, 2010. A total of 75 participants, of which close to 40 were from outside India attended the conference and a large fraction of them presented papers. The conference also featured a number of review talks on topics relevant to the study of reionization.
2. 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 Jhunsi.
3. I am the secretary of the Astronomical Society of India from Jan.2010-Dec.2012.

Sandhya Choubey

Extraordinary success of neutrino experiments in the last few decades has propelled neutrino physics to the centre stage of particle physics. Current interest in this field resolves around the calculation of the physics reach of the forthcoming and proposed experiments as well as in building a model of elementary particles which would be able to incorporate observation of neutrino masses and mixing in addition to all other observations. The standard model of particle physics fails to provide a suitable explanation for the neutrino masses and mixing pattern. A natural explanation for such tiny neutrino masses is provided by postulating an effective 5-dimensional operator, the only one consistent with the SM, leading to Majorana neutrino masses suppressed by a high mass scale. In the see-saw mechanism, such an operator is generated when a heavy particle gets integrated out from the theory, where, under the SM gauge group SU(2)$_L$ $\times$U(1)$_Y$, the heavy particle can either be a singlet fermion with $Y = 0$, a triplet scalar with $Y = 2$, or a triplet fermion with $Y = 0$. The three cases are known as the type I, type II, or type III see-saw mechanisms, respectively.

In a paper now published in JHEP, my student Manimala Mitra and I proposed a two Higgs doublet Type III seesaw model with μ-τ flavor symmetry. The presence of two Higgs doublets allows for natural explanation of small neutrino masses with triplet fermions in the 100 GeV mass range, without fine tuning of the Yukawa couplings to extremely small values. The triplet fermions couple to the gauge bosons and can be thus produced at the LHC. We studied in detail the effective cross-sections for the production and subsequent decays of these heavy exotic fermions. We showed for the first time that the μ-τ flavor symmetry in the low energy neutrino mass matrix results in mixing matrices for the neutral and charged heavy fermions that are not unity and which carry the flavor symmetry pattern. This flavor structure can be observed in the decays of the heavy fermions at LHC. The large Yukawa couplings in our model result in the decay of the heavy fermions into lighter leptons and Higgs with a decay rate which is about 10^{11} times larger than what is expected for the one Higgs Type III seesaw model with 100 GeV triplet fermions. The smallness of neutrino masses constrains the neutral Higgs mixing angle $\sin\alpha$ in our model in such a way that the heavy fermions decay into the lighter neutral CP even Higgs h^0, CP odd Higgs A^0 and the charged Higgs $H^\pm$, but almost never to the heavier neutral CP even Higgs H^0. The small value for $\sin\alpha$ also results in a very long lifetime for h^0. This displaced decay vertex should be visible at LHC. We provided an exhaustive list of collider signature channels for our model and identified those that have very large effective cross-sections at LHC and almost no standard model background.

Among the main drawbacks of the standard model is the problem of explaining the stability of the Higgs mass. Supersymmetry in particle physics has been one of the most widely accepted way of alleviating this problem. The most general superpotential allows for terms which break lepton num-

ber and baryon number. However these lepton and baryon number violating couplings are severely constrained by non-observation of proton decay and data on heavy flavor physics from Belle and Babar. In order to avoid all such terms in the superpotential, one imposes a Z_2 symmetry called R-parity, which is defined as $R_p = (-1)^{3(B-L)+2S}$, where B and L are the baryon and lepton number of the particle and S is the spin. In the limit where R-parity is conserved both lepton and baryon number are conserved, whereas the breaking of R-parity ensures the breaking of lepton and/or baryon number. On the other hand, allowing for breaking of R-parity opens up the possibility of generating Majorana mass terms for the neutrinos In a paper due to be published in JHEP we presented a model where neutrino masses are generated by a combination of spontaneous R-parity violation and Type III seesaw. In addition to the usual MSSM particle content, our model consists of one extra triplet matter chiral superfield containing heavy SU(2) triplet fermions and its superpartners. R-parity is broken spontaneously when the sneutrinos associated with the one heavy neutrino as well as the three light neutrinos get vacuum expectation values, giving rise to the mixed 8×8 neutralino-neutrino mass matrix. We showed that our model can comfortably explain all the existing neutrino oscillation data. Due to the presence of the triplet fermion, we have a pair of additional heavy charged leptons which mix with the standard model charged leptons and the charginos. This gives rise to a 6×6 chargino-charged lepton mass matrix, with 6 massive eigenstates. Finally we discussed about the different R-parity violating possible decay modes and the distinctive collider signatures which our model offers.

Neutrino telescopes such as IceCube have been designed to observe ultra high energy neutrinos coming from distant astrophysical sources. These flavor ratios of these neutrinos at the detector can be used to lend information about the nature of the source. In paper published in Physical Review D, we parameterize the initial flux composition of high energy astrophysical neutrinos as ($\Phi_e^0 : \Phi_m u^0 : \Phi_t a u^0$) = (1 : n : 0), where n characterizes the source. All usually assumed neutrino sources appear as limits of this simple parametrization. We investigated how precise neutrino telescopes can pin down the value of n. We furthermore showed that there is a neutrino mixing scenario in which the ratio of muon neutrinos to the other neutrinos takes a constant value regardless of the initial flux composition. This occurs when the muon neutrino survival probability takes its minimal allowed value. The phenomenological consequences of this very predictive neutrino mixing scenario were given.

In another work, along with my collaborators at HRI, we studied the spectral distortions of diffuse ultra high energy neutrino flavour fluxes resulting due to physics beyond the Standard Model. Even large spectral differences between flavours at the source are massaged into a common shape at earth by SM oscillations, thus, any significant observed spectral differences are an indicator of new physics present in the oscillation probability during propagation. Neutrino decay and Lorentz symmetry violation were taken as examples, and they result in significant distortion of the fluxes and the well-known bounds on

them, which may allow UHE detectors to probe lifetimes, the mass hierarchy and LV parameters over a broad range.

Neutrino-neutrino interactions inside core-collapse supernovae may give rise to flavor oscillations resulting into collective swap of flavors. These oscillations depend on the initial energy spectra and initial relative fluxes or initial luminosities of the neutrinos. It has been observed that departure from energy equipartition among different flavors can give rise to one or more sharp spectral swap over energy termed as splits. We studied the occurrence of splits in the neutrino and antineutrino spectra varying the initial relative fluxes for different models of initial energy spectrum in both normal and inverted hierarchy. These initial relative flux variations give rise to several possible split patterns where as variation over different models of energy spectra give similar results. We explored the effect of these spectral splits on the electron fraction, Y_e, that governs r-process nucleosynthesis inside supernovae. Assuming the condition $Y_e < 0.5$, needed for successful r-process nucleosynthesis we presented exclusion plots of the initial luminosities or relative fluxes, including the effect of collective oscillations.

Precision measurement of neutrino oscillation parameters is the most important immediate goal in neutrino physics. We proposed a realistic Beta-Beam experiment with four source ions and two baselines for the best possible sensitivity to oscillation parameters. Neutrinos from 18Ne and 6He with Lorentz boost gamma=350 are detected in a 500 kton water Cerenkov detector at a distance L=650 km (first oscillation peak) from the source. Neutrinos from 8B and 8Li are detected in a 50 kton magnetized iron detector at a distance L=7000 km (magic baseline) from the source. Since the decay ring requires a tilt angle of 34.5 degrees to send the beam to the magic baseline, the far end of the ring has a maximum depth of d=2132 m for magnetic field strength of 8.3 T, if one demands that the fraction of ions that decay along the straight sections of the racetrack geometry decay ring (called livetime) is 0.3. We alleviated this problem by proposing to trade reduction of the livetime of the decay ring with the increase in the boost factor of the ions, such that the number of events at the detector remains almost the same. This allows to substantially reduce the maximum depth of the decay ring at the far end, without significantly compromising the sensitivity of the experiment to the oscillation parameters. We take 8B and 8Li with gamma=390 and 656 respectively, as these are the largest possible boost factors possible with the envisaged upgrades of the SPS at CERN. This allows us to reduce d of the decay ring by a factor of 1.7 for 8.3 T magnetic field. Increase of magnetic field to 15 T would further reduce d to 738 m only. We studied the sensitivity reach of this two baseline two storage ring Beta-Beam experiment, and compare it with the corresponding reach of the other proposed facilities.

Publications:

1. Priyotosh Bandyopadhyay, Sandhya Choubey, Manimala Mitra, *Two Higgs Doublet Type III Seesaw with mu-tau symmetry at LHC,* JHEP **0910**, 012, (2009)
2. Sandhya Choubey, Pilar Coloma, Andrea Donini, Enrique Fernandez-Martinez *Optimized Two-Baseline Beta-Beam Experiment,* JHEP **0912**, 020, (2009)
3. Sandhya Choubey, Werner Rodejohann, *Flavor Composition of UHE Neutrinos at Source and at Neutrino Telescopes,* Phys. Rev. D **80**, 113006, (2009)
4. Atri Bhattacharya, Sandhya Choubey, Raj Gandhi, Atsushi Watanabe, *Diffuse Ultra-High Energy Neutrino Fluxes and Physics Beyond the Standard Model,* doi.10/10/16/j.physletb.2010.04.078 Phys. Lett. B (2010)
5. Sandhya Choubey, Manimala Mitra, *Spontaneous R-Parity Violating Type III Seesaw,* JHEP **1005**, 021, (2010)

Preprints:

1. Sovan Chakraborty, Sandhya Choubey, Srubabati Goswami, Kamales Kar, *Diffuse Ultra-High Energy Neutrino Fluxes and Physics Beyond the Standard Model,* arXiv:0911.1218 [hep-ph]
2. Sandhya Choubey, Steve King, Manimala Mitra, *On the Vanishing of the CP Asymmetry in Leptogenesis due to Form Dominance,* arXiv:1004.3756 [hep-ph]
3. Sandhya Choubey, Thomas Schwetz, Chris Walter, *NuFact'09 Working Group I Report (Theory),* To be published in the proceedings of NuFact'09

Conference/Workshops Attended:

1. *Astroparticle Physics – A Pathfinder to New Physics*, Sweden, April, 2009.
2. *Sixth International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region, NuInt'09*, Spain, May, 2009.
3. *11th International Workshop on Neutrino Factories, Superbeams and Beta Beams, NuFact'09*, USA, July, 2009.
4. *22nd International Workshop on Weak Interactions and Neutrinos, WIN'09*, Italy, September, 2009.

Visits to other Institutes:

1. Max-Planck-Institute for Nuclear Physics, Heidelberg, Germany, May, 2009.
2. Scoula Internazionale Superiore di Studi Avanzati, Trieste, Italy, May, 2009.
3. Saha Institute of Nuclear Physics, Kolkata, India, May, 2009.

Invited Lectures/Seminars:

1. *The India-based Neutrino Observatory*, seminar, MPI-K Heidelberg, Germany, May 2009.
2. *Plenary talk on "Summary of Working Group I: Theory"*, 11th International Workshop on Neutrino Factories, Superbeams and Betabeams, NuFact'09, Chicago, USA, July, 2009.
3. *Plenary talk on "Neutrino Physics: Theoretical Status"*, 22nd International Workshop on Weak Interactions and Neutrinos, WIN'09, Perugia, Italy, September, 2009.

Academic recognition/Awards:

- PI of Joint research proposal under Indo-German (DST-DFG) S&T Cooperation Programmme, 2010-2013.

Organizing schools/conferences:

1. Convernor of the Neutrino Oscillation Physics (WG1) of the 22nd International Workshop on Neutrino Factories, Superbeams and Betabeams, NuFact09, Chicago, USA, July, 2009.
2. Member of the Scientific Program Committee (SPC) and convenor of the "Current and Future Experiments" session at the "Sixth International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region", NUINT09, Sitges, Barcelona, Spain, May 2009.
3. Member of the organizing committee of "NuHoRIzons, Neutrinos in Physics, Astrophysics and Cosmology", held at HRI, Allahabad, January 2010.

Other Activities:

1. Teaching at HRI: Fourth semester course on "Computational Methods", 2010.
2. Mentoring PhD Students:
   (a) Manimala Mitra (Ms. Mitra has submitted her PhD synopsis)
   (b) Ram Lal Awasthi
3. Thesis Examination for a Ph.D. degree
   - Examined the Ph.D. thesis of Shamayita Ray from TIFR, Mumbai and took her viva voce examination.
4. Reviewing Papers: Refereed papers for
   (a) Physical Review Letters
   (b) Physical Review D

(c) New Journal of Physics

5. Talks at HRI:

   (a) *Flavor symmetries, leptogenesis and the absolute neutrino mass scale*, on arXiv:0908.0161 by E. Bertuzzo, P. Di Bari, F. Feruglio, E. Nardi pheno-lunch on August 18, 2009.

6. Committees Served:

   (a) Office and Furniture Committee (Convenor)

   (b) Guest House and Pantry (Member)

   (c) Women Grievance Cell (Convenor)

Tirthankar Roy Choudhury

My main research interests lie in the field of Cosmological reionization and the Intergalactic Medium. In recent times, I have been working on (i) constraining theoretical models of cosmological reionization using a principal component analysis techniques, (ii) theoretical predictions on detecting the signal from cosmological neutral hydrogen by cross-correlating the 21cm hyperfine transition signal with the Lyα transition signal, (iii) detailed modelling of the intergalactic medium through Lyα forest at redshifts $z \sim 3$.

Publications:

1. Kanan Datta, Somnath Bharadwaj, T. Roy Choudhury, *The optimal redshift for detecting ionized bubbles in HI 21-cm maps,* Monthly Notices of the Royal Astronomical Society **399**, L132, (2009)
2. Tirthankar Roy Choudhury, *Analytical Models of the Intergalactic Medium and Reionization,* Current Science **97**, 841, (2009)

Preprints:

1. Tapomoy Guha Sarkar, Somnath Bharadwaj, Tirthankar Roy Choudhury, Kanan Datta, *Cross-correlation of the Lyman-alpha Forest and HI 21 cm: A Probe of Cosmology,* arXiv:1002.1368

Conference/Workshops Attended:

1. *ICCGF'09: INDIAN CONFERENCE ON COSMOLOGY AND GALAXY FORMATION - 2009*, Indian Institute of Technology, Kanpur, India, October 2009.
2. *Cosmological Reionization*, Harish-Chandra Research Institute, Allahabad, India, February 2010.

Invited Lectures/Seminars:

1. *Astronomy: Past and Future*, Invited popular talk in the *37th Jawaharlal Nehru State Level Children Science Exhibition* organized by the Uttar Pradesh State Institute of Science Education, Allahabad, India, November 2009.
2. *Observational Constraints on Reionization History*, Invited talk in Cosmological Reionization, Harish-Chandra Research Institute, Allahabad, India, February 2010.

Other Activities:

1. Member, Graduate Studies Committee (Physics).
2. Member, Computer Committee.

3. Full-semester course on *Mathematical Physics* in the for graduate students in Physics, August-December 2009.
4. Full-semester reading course on *Cosmology* in the for graduate students in Physics, January-May 2010.
5. Project: Sourav Mitra (HRI graduate student) on *Principal Component Analysis of the Reionization History*, January-May 2010.
6. KVPY project: Shubham Yadav (Boys' High School and College, Allahabad) on *The Hubble Diagram*, June 2009.
7. VSP project: Kshitiz Mallick on *Big Bang Nucleosynthesis*, June 2009.
8. External examiner for M.Phil. thesis of Stephen Petrie, University of Melbourne, Australia.

Tapas Kumar Das

1. Collaborators: Bozena Czerny (Polish Academy of Science), Mihaw Dovciak, Vladimir Karas & T. Pechacek (Academy of Science, Czech Republic) and Pawel Lachowicz (National University of Singapore)

   Quasi Periodic Oscillation in Active Galactic Nuclei

   RE J1034+396 is the active galactic nuclei (AGN) for which the first robust detection of a Quasi Periodic Oscillation (QPO) has been performed. Our novel Wavelet Analysis Technique confirms that the QPO detected in the aforementioned candidate likely shows a drift of the oscillation period correlated with the change of the X-ray luminosity. Also we demonstrate, using a specific scenario of the oscillation mechanism in black hole accretion disc, that modeling such a correlated trends implies very strong constraints on the nature of the this oscillation and the character of the hot flow in AGN.

   IXO should bring more active galaxies with temporary observed quasi-periodic oscillations so similar study for other scenarios will be necessary.
2. Collaborators: Sankhasubhra Nag & Suparna Roychowdhury (St. Xavier College, Kolkata, India) and Viswas Srivastava, (IISER, Kolkata, India)

   Onset of Chaos in Astrophysical Dynamics

   The Hill problem as one of the simplest non-integrable cases attracted the attention from the physicists since long. But in recent years a renewed interest has been generated in connection to the motion of a test particle around a binary star when one of the binary companions is a black hole. We studied the problem for various forms of pseudo-potentials for Schwarzschild as well as Kerr cases and the essential features common to all the cases irrespective of the forms of pseudo-potentials.

   The study on the motion of the object (test particle) around a black hole with a dipolar, quadrupolar perturbing interaction (halo) and the possibility of chaotic behaviour drew much attention in recent years. We studied the problem for pseudo Kerr potentials with dipolar halo and compared the result for different strengths of Kerr parameter where the earlier studies on Schwarzschild case comes as a limiting case.

Preprints:

1. Das, Tapas K., (with Czerny, Bozena, Lachowicz, Pawel, Dovciak, Mihaw, Karas, Vladimir & Pechacek, T.), *The model constraints from the observed*

trends for the quasi-periodic oscillation in RE J1034+396.
2. Das, Tapas K., (with Czerny, Bozena), *Modelling the QPO in AGNs*.
3. Das, Tapas K., (with Nag, Sankhasubhra & Roychowdhury, Suparna), *The chaotic features of pseudo-Newtonian Hill problems*.
4. Das, Tapas K., (with Nag, Sankhasubhra & Srivastava, Viswas), *Chaos in pseudo Kerr black holes with dipolar halos*.

Visits to other Institutes:

1. Raman Research Institute, **Bangalore, India**, April, 2009.
2. Saha Institute of Nuclear Physics, **Calcutta, India**, April, 2009.
3. University of Vienna, **Vienna, Austria**, May, 2009.
4. N. Copernicus Astronomical Institute, Polish Academy of Science, **Warsaw, Poland**, May - July, 2009.
5. Marian Smoluchowski Institute of Physics. Jagiellonian University,, **Cracow, Poland**, June, 2009.
6. Astronomical Institute of the Academy of Sciences of the Czech Republic, **Prague, Czech republic**, July, 2009.
7. St Xavier College **Calcutta, India**, October and December, 2009.
8. Visva Bharati University, **Santiniketan, India**, February, 2010.

Invited Lectures/Seminars:

1. Colloquium at Raman Research Institute, Bangalore, India, on 'Analogue gravity in classical fluid and in the Bose Einstein Condensate', April, 2009.
2. Colloquium at Saha Institute of Nuclear Physics, Calcutta, India, on 'Black hole in your bathtub', April, 2009.
3. Colloquium at University of Vienna, Vienna, Austria, on 'Analogue Gravity in Astrophysics and Cosmology', May, 2009.
4. Seminar at University of Vienna, Vienna, Austria, on 'Aspects of low angular momentum relativistic accretion', May, 2009.
5. Colloquium at N. Copernicus Astronomical Institute, Warsaw, Poland, on 'On the role of black hole spin in influencing the terminal behavior of accretion flow', May, 2009.
6. Seminar at Marian Smoluchowski Institute of Physics. Jagiellonian University, Cracow, on 'Accretion onto Black Hole: A Dynamical Systems Approach', June, 2009.
7. Seminar at Astronomical Institute of the Academy of Sciences of the Czech Republic (Group of Relativistic Astrophysics) in Prague, on *General relativistic black hole accretion as dynamical systems*, July, 2009.
8. Public Lecture at St Xavier College, Calcutta University, on *Astrophysical Black Holes*, October 2009.
9. *Black Holes in Astrophysics*, popular lecture at Visva Bharati University, Santiniketan, India, February, 2010.

10. *Transonic Astrophysical Accretion*, seminar at Visva Bharati University, Santiniketan, India, February, 2010.

Other Activities:

1. **Acting as Proposal Reviewer/ Journal Referee**
   (a) Served as the reviewer of the international research grant proposals submitted by astrophysicists from abroad to the Science Foundation/ Ministry of Science of European countries.
   (b) Served as a referee for various International journals.
2. Teaching
   (a) **Graduate Course:** Astrophysical Processes, August - December 2009. Sole instructor.
3. Project Supervision
   (a) Manoj K. Mondal, a post B.Sc. HRI graduate student, did a reading project with me on Aspects of Astrophysical Fluid Dynamics.
4. Mentoring Students
   (a) MS. Swathi Hegde, final year M.Sc. (post graduate) student of Mysore University, India.
   (b) Mr. Swagata Acharya, final year B.Sc. (under graduate) student Ramakrishna Mission Vidyamandira, Belur, Kolkata.
   (c) Mr. Viswas Shrivastava, second year B.Sc. (under graduate) student of Indian Institute of Science Education and Research, Kolkata, India.
5. **Administrative Work**
   (a) Served as a member of the Medical Committee at HRI.

AseshKrishna Datta

During 2009-2010, I worked in the following areas:

I was involved in projects on collider studies of a specific extra-dimensional scenario like the Universal Extra Dimensions (UED). We have incorporated the UED in an event generator like CompHEP/CalcHEP. This allows us to study interesting processes (with multi-particle final states) at present and future colliders in an exact and exhaustive way at the lowest order in perturbation theory. Incidentally, this is the *first ever* implementation of the scenario in an event-generator which was made publicly available.

During last one year we have carried out a project on the hitherto unexplored collider aspects of the scalar (Higgs) sector of the Universal Extra Dimensions. The project was computationally challenging as well. In a recent (published) work we demonstrated the potential of the Large Hadron Collider (LHC) to probe the physics of such a sector.

I have also been studying the techniques to determine the mass and the spin of the new particles that can be found at the LHC.

I am also involved in streamlining the usage of the Monte Carlo event generators along with other advanced software tools for High Energy Physics phenomenology with a goal to build an integrated analysis-platform for LHC physics.

Publications:

1. AseshKrishna Datta, Priyotosh Bandyopadhyay, Biplob Bhattacherjee, *Search for Higgs bosons of the Universal Extra Dimensions at the Large Hadron Collider,* Journal of High Energy Physics **1003**, 048, (2010).

Preprints:

1. AseshKrishna Datta, Kyoungchul Kong, Konstantin T. Matchev, *Minimal Universal Extra Dimensions in CalcHEP/CompHEP,* e-Print: arXiv:1002.4624 [hep-ph], Accepted for publication in New Journal of Physics.

Conference/Workshops Attended:

1. *Data to theory at the LHC*, IIAS, Shimla, India, December, 2009.
2. *Workshop on LHC Physics*, Tata Institute of Fundamental Research, India, October, 2009.
3. *Joint ICTP-INFN-SISSA Conference: Topical Issues in LHC Physics*, Trieste, Italy, June-July, 2009.
4. *Workshop on Physics at TeV Colliders*, Les Houches, France, June, 2009.

Visits to other Institutes:

1. Theory Division, CERN, Switzerland, May-June, 2009.
2. *Theoretical Physics Group, Indian Association for Cultivation of Science*, Kolkata, India, May and December, 2009.

Invited Lectures/Seminars:

1. *Measuring Masses at the LHC: A review of techniques proposed (a set of 3 lectures)*, in Data to Theory at the LHC, organised by Institute of Mathematical Sciences, Chennai and Regional Centre for Accelerated-based Particle Physics, Indian Institute of Advanced Study (IIAS), Shimla, December, 2009.
2. *Deciphering New Physics at LHC*, Workshop on LHC Physics, Tata Institute of Fundamental Research, Mumbai, India, October, 2009.

Other Activities:

1. Supervised a graduate student at HRI who successfully defended his Ph.D. thesis in December, 2009 and joined a postdoctoral position abroad subsequently.
2. Started supervising a graduate student (towards a Ph.D. degree) since the beginning of 2010.
3. Gave a semester-long graduate course on Classical Electrodynamics during fall, 2009.
4. Supervised two semester-long projects/reading-courses at HRI during fall and spring semesters of 2009-2010.
5. Supervised a project-intern from another institute.
6. Served as an examiner of a Ph.D. thesis from a renowned academic institute.
7. Served as referees for national and international peer-reviewed journals.
8. Organised (with specific charge), along with my colleagues at RECAPP, HRI, an outreach programme jointly with IISER, Kolkata at the Science City auditorium, Kolkata in October, 2009.
9. Serving as the Technical Coordinator of the Regional Centre for Accelerator-based Particle Physics (RECAPP) at HRI since April, 2007.
10. Serving the Computer Committee for the third year in a row and currently as its Convener.
11. Serving as an ex-officio member of the technical team constituted at HRI for overseeing the setting up of the HRI-node of the National Knowledge Network (NKN).
12. Serving as a member of the committee for the Cluster Computing Facility at HRI.
13. Serving the Sports and Entertainment Committee of HRI for the third year in a row and as the Convener of the same for the last two consecutive

years.

14. Served in a committee constituted by the Director, HRI to bring the existing Housing Rules at HRI in line with the 6th CPC.

Aditi Sen De

Quantum correlations aka entanglement has been identified as a key resource in quantum information processing. It has been argued, and tested for several many-body systems, that entanglement can be used as a "universal detector" of quantum phase transitions, with most of the studies being on the behavior of *bipartite* entanglement. However, a more natural candidate to study many-body systems would be to consider multipartite entanglement. The main obstacle in such an enterprise is the lack of a multipartite entanglement measure, that is physically satisfying and, at the same time, mathematically tractable. We have introduced a genuine multipartite entanglement measure, motivated by the geometry of the space of multipartite states. We have shown that it can be reduced to a closed form. We use this measure for studying different phases in many-body systems. Such systems include several frustrated quantum spin models, resonating valence bond (RVB) states, etc. We propose an order parameter that has its origin in the multipartite entanglement measure, and that can recognize the gapless and gapped phases of the frustrated quantum models by its sign.

During the last year, we have also found that the geometry of a lattice can have important implications on the quality of quantum information and other tasks that can be performed by using multiparty states on that lattice. An RVB liquid on a ladder lattice has substantial bipartite entanglement on its steps, while that on its rails is insignificant, implying that genuine multipartite entanglement of this multiparty quantum state is negligible. This is in sharp contrast with the situation for the RVB liquid on isotropic two-dimensional or three-dimensional lattices, where the single type of nearest neighbor entanglement is negligible, while the state is genuine multiparty entangled.

We have also focused on the different aspects of multi-access quantum communication protocols. For quantum states of two subsystems, entanglement measures are related to capacities of communication tasks – highly entangled states give higher capacity of transmitting classical as well as quantum information. However, we have shown that this is no more the case in general: quantum capacities of multi-access channels, motivated by communication in quantum networks, do not have any relation with genuine multiparty entanglement measures.

Publications:

1. Aditi Sen (De) and Ujjwal Sen, *Channel capacities versus entanglement measures in multiparty quantum states*, Phys. Rev. A **81**, 012308, (2010).

Preprints:

1. Aditi Sen (De) and Ujjwal Sen, *Entanglement Mean Field Theory and the Curie-Weiss Law*, arXiv:0911.4856.

2. Aditi Sen (De) and Ujjwal Sen, *Bound Genuine Multisite Entanglement: Detector of Gapless-Gapped Quantum Transitions in Frustrated Systems*, arXiv:1002.1253.
3. Himadri Shekhar Dhar and Aditi Sen (De), *Geometry versus Entanglement in Resonating Valence Bond Liquids*, arXiv:1003.4401.

Conference/Workshops Attended:

1. *International Conference on Cold Ions and Atoms 2010*, India, January, 2010.
2. *International Program on Quantum Information (IPQI-2010)*, India, January, 2010.

Invited Lectures/Seminars:

1. *Distributed Quantum Information Processing*, Invited talk in International Conference on Cold Ions and Atoms 2010, Raman Center for Atomic, Molecular and Optical Sciences, and International Centre for Theoretical Sciences, held at Shankarpur, January, 2010.
2. *Quantum Information Methods in Complex Systems*, Invited talk in International Program on Quantum Information (IPQI-2010), Institute of Physics, and International Centre for Theoretical Sciences, held at Bhubaneswar, January, 2010.

Other Activities:

1. Guided a project of a second-year HRI graduate student, Saurabh Pradhan, entitled "Quantum information processing with disordered systems". Jan-May, 2010.
2. Served as referees in international journals.

Raj Gandhi

With my student, Atri Bhattacharya, Sandhya Choubey and Atsushi Watanabe, we have performed a detailed study of the consequences of physics beyond the Standard Model (SM) on ultra-high energy (UHE) neutrinos. In the presence of important new physics, like tiny Lorentz invariance violations, neutrino decay, quantum decoherence and CP violations, UHE neutrino flavour fluxes undergo significant distortions from their expected spectral shapes and relative magnitudes. We have studied the consequences for extant and upcoming UHE detectors in the presence these effects.

The neutrino mass hierarchy remains an important unknown which must be determined in order to build theories beyond the SM. Additionally, with the recent MINOS results, the possibility that one of the important unknowns in particle physics, the neutrino mixing angle θ_{13} is small has been re-opened. Most existing discussions on determining the hierarchy have relied on the fact that θ_{13} is not tiny. A small value for this parameter would require a completely different approach towards detection of the hierarchy. With Atri Bhattacharya, and another graduate student Manoj Mondal, we are exploring the possibility of detection of the hierarchy if θ_{13} is zero or very tiny.

Publications:

1. R. Gandhi, A. Samanta and A. Watanabe, , *The Role and Detectability of the Charm Contribution to Ultra High Energy Neutrino Fluxes, ,* JCAP **0909**, 015 (2009)

2. R. Gandhi, P Ghoshal, S. Goswami and U. Sankar , *Mass hierarchy determination for $\theta_{13} = 0$ and atmospheric ,* To appear in Mod.Phys.Lett.A

3. A. Bandyopadhyay *et al.* [ISS Physics Working Group], , *Physics at a future Neutrino Factory and super-beam facility, ,* Rept. Prog. Phys. **72**, 106201 (2009)

Preprints:

1. A. Bhattacharya, S. Choubey, R. Gandhi and A. Watanabe, *Diffuse Ultra-High Energy Neutrino Fluxes and Physics Beyond the Standard Model,,* arXiv:0910.4396 [hep-ph]
2. A. Bhattacharya, S. Choubey, R. Gandhi and A. Watanabe, *Ultra-High Energy Neutrinos as a probe for non-standard physics,* (in preparation)

Visits to other Institutes:

1. Theory Group, Fermilab May-June 15 2009,
2. Theory Group, Argonne National Lab,, USA, June 2009.
3. Theory Group, Brookhaven National Lab USA, June 2009.

4. Theory Group, University of Kansas USA, July 2009.

Invited Lectures/Seminars:

1. *The Physics Role and Potential of future Atmospheric Detectors*, Plenary Talk, NuFACT 2009, Chicago, July 2009.
2. *Diffuse UHE fluxes and Physics beyond the Standard Model*, Theory Seminar, Fermilab, , July 2009.
3. *Diffuse UHE fluxes and Physics beyond the Standard Model*, Theory Seminar, Argonne National Lab, , June 2009.
4. *Diffuse UHE fluxes and Physics beyond the Standard Model*, Theory Seminar, Brookhaven National Lab, , June 2009.
5. *Diffuse UHE fluxes and Physics beyond the Standard Model*, Theory Seminar, U of Kansas, , July 2009.

Other Activities:

1. Atri Bhattacharya continues to work towards his Ph.D under my supervision and will be starting his fourth year in Fall '10
2. I have taught the Particle Physics course for our second year graduate students in Fall 09.
3. I have guided Manoj Mondal for his graduate project in Fall 09, and Manoj Mondal and Ujjal Dey for their graduate projects in Spring 10.
4. I am actively involved in the INO project, am a member of its Program management Committee and the Co-ordinator for Physics Studies for INO.
5. I am a member of the International Design Study for a Neutrino Factory.
6. I am a member of the UKIERI project, which is a research project involving Indian and UK scientists.

Rajesh Gopakumar

With Justin David and Matthias Gaberdiel, we completed the evaluation of the heat kernel of the laplacian on AdS_3 for particles of arbitrary spin. This result captures the full one loop answer for the bulk propagating modes in anti de Sitter and is likely to be of use in the further study of the AdS/CFT correspondence in this case. In fact, the result was immediately applied to derive the $\mathcal{N} = 1$ supergravity one loop answer which had the form of a vacuum character of an $\mathcal{N} = 1$ supervirasoro character. We continue to pursue our studies and have since generalised our answers to the case of the superstring on AdS_3 with NS-NS flux. The exact one loop answer of the string theory is precisely in the form of a sum of heat kernel contributions of the particles in the string spectrum (which carry arbitrarily large spin). In fact, the proper time of the heat kernel can be regarded as the (imaginary part of the) modular parameter of the worldsheet torus. This encourages hope of obtaining worldsheet expressions in more general contexts such as at the point in moduli space dual to the symmetric product orbifold CFT. We are currently pursuing this line of research.

We have also been continuing with our investigation of the Galilean Conformal Algebra (GCA) as an interesting nonrelativistic limit of usual CFTs particularly in the context of the AdS/CFT conjecture. With Arjun Bagchi, Ipsita Mandal and Akitsugu Miwa we investigated the quantum mechanical realisation of the GCA in the case of two spacetime dimensions. Here one is to take a nonrelativistic limit of 2d CFTs which are very thoroughly studied for their applications in string theory, statistical mechanics etc. We found that at the quantum level one needs to consider an unusual limit of the parent relativistic CFT in which the central charges (of the left and right) are large in magnitude and opposite in sign. The resulting group contraction of the two copies of the Virasoro algebra precisely gives the GCA in 2d, now with central extensions. We studied various aspects of this limit which appears to be a consistent one in that various features of the CFT have a well defined limit and often make sense through an independent definition within the GCA. This gives confidence in the ability to apply the GCA at the quantum level though more consistency checks need to be done. Ipsita Mandal has further generalised some of these considerations to the supersymmetric case.

Publications:

1. Arjun Bagchi and R. Gopakumar, *Galilean Conformal Algebras and AdS/CFT*, JHEP **0907**, 037, (2009).
2. J. R. David, M. Gaberdiel and R. Gopakumar, *The Heat Kernel on AdS_3 and its Applications*, JHEP **1004**, 125, (2010).

Preprints:

1. Arjun Bagchi, Rajesh Gopakumar, Ipsita Mandal and Akitsugu Miwa *GCA in 2d,* arXiv.org:0912.1090 (hep-th)

Conference/Workshops Attended:

1. *KITP Workshop on Fundamental Problems in String Theory*, KITP, Santa Barbara, USA, Apr.-May, 2009.
2. *String Theory: Perspectives from a New Generation*, IST, Lisbon, Portugal, Jun. 2009.
3. *5th Crete Workshop on String Theory*, Kolymbari, Greece, Jul. 2009.
4. *Quantum Theory and Symmetries (QTS6)*, Lexington, Kentucky, USA, Jul.2009.
5. Young Indian Scientists Colloquium, Bhabha Centenary meet, TIFR, Mumbai, Sep. 2009.
6. *Global Young Scientists Meet, World Economic Forum* Dalian, China, Sep. 2009.
7. *INSA Platinum Jubilee Meeting*, Kolkata, Dec. 2009.
8. *Science without Boundaries: ICTS inaugural event*, Bangalore, India, Dec. 2009.
9. *Discussion meeting on String Theory*, TIFR, Mumbai, Jan. 2010.
10. *Bhabha Centenary Meeting*, BHU, Varanasi, Jan. 2010.
11. *National Strings Meeting*, IIT-Bombay, Mumbai, Feb. 2010.

Visits to other Institutes:

1. KITP, Santa Barbara, USA, Apr.-May, 2009.
2. TIFR, Mumbai, Jun. 2009.
3. Albert Einstein Institute, Potsdam, Germany, Jul. 2009.
4. LPTHE, Univ. of Paris, Jul. 2009.
5. IISER, Bhopal, Nov. 2009.
6. TIFR, Mumbai, Jan. 2010.
7. St. Stephen's College, Delhi University, Feb. 2010.
8. JNU, New Delhi, Mar. 2010.

Invited Lectures/Seminars:

1. *Galilean Conformal Field Theories and AdS/CFT*, String Theory Seminar, Univ. of Southern California, Los Angeles, USA, May 2009.
2. *Galilean Conformal Field Theories and AdS/CFT*, String Theory Seminar, KITP, Santa Barbara, May 2009.
3. *The Heat Kernel on AdS_3 and its Applications*, String Theory Seminar, TIFR, Mumbai, Jun. 2009.
4. *Galilean Conformal Field Theories and AdS/CFT*, Lectures at the Lisbon conference, IST, Lisbon, Jun. 2009.

5. *The Heat Kernel on AdS_3 and its Applications*, String Theory Seminar, AEI, Potsdam, Jul. 2009.
6. *Galilean Conformal Field Theories and AdS/CFT*, Talk at the Crete conference, Crete, Greece, Jul. 2009.
7. *Galilean Conformal Field Theories and AdS/CFT*, Talk at the QTS6 conference, Kentucky, USA, Jul. 2009.
8. *Spacetime and String Theory*, Young Indian Scientists Colloquium, TIFR, Mumbai, Sep. 2009.
9. *Spacetime and String Theory*, Physics Colloquium, IISER, Bhopal, Nov. 2009.
10. *GCA in 2d*, String Discussion Meet, TIFR, Mumbai, Jan. 2010.
11. *From Fields to Strings*, Bhabha Centenary Meeting, BHU, Varanasi, Jan. 2010.
12. *Gaiotto Dualities*, National Strings Meeting, IIT-Bombay, Mumbai, Feb. 2010.
13. *String Theory and The Quest for Quantum Spacetime*, Popli Memorial Lectures, St. Stephen's College, New Delhi, Feb. 2010.
14. *Aspects of Galilean Conformal Invariance*, Physics Seminar, JNU, New Delhi, Mar. 2010.

Academic recognition/Awards:

- Shanti Swarup Bhatnagar Award 2009 (Physical Sciences), Sep. 2009.
- Elected Fellow of the Indian National Science Academy (INSA), New Delhi, Sep. 2009.
- Delivered Popli Memorial Lectures, St. Stephen's College, New Delhi, Feb. 2010.

Other Activities:

1. Member, Organising Committee, 3rd Asian Winter School on String Theory, Particle Physics and Cosmology, Mahabaleshwar (Jan. 2010).
2. Member, Program Committee, International Centre for Theoretical Sciences (ICTS).
3. Member of various academic and administrative committees at HRI.
4. Contributed article *"Spacetime and String Theory"* to INSA, Gujarat semi-popular book (ed. U. Sarkar).
5. Contributed article *What is the AdS/CFT correspondence?"*, **Physics News**, Jan. 2010 issue.

Pinaki Majumdar

I have continued work on clarifying the effect of antisite domains on the physical properties of double perovskite magnets. This includes analysis of the transport/localisation effects, as well as spatial correlations, spin polarisation etc. In addition we have built up a global phase diagram of such materials in the 3D situation. With Subrat Das we are computing the magnetic fluctuation spectrum to correlate with the spatial textures. We have started on an analysis of Coulomb interaction effects in these systems.

Publications:

1. Prabuddha Sanyal and Pinaki Majumdar, *Magnetic model for the ordered double perovskites*, Phys. Rev. **B 80**, 054411 (2009).

Preprints:

1. Vivekanand Singh and Pinaki Majumdar, *Antisite Domains in Double Perovskite Ferromagnets: Impact on Magnetotransport and Half-metallicity,* (in preparation).
2. Rajarshi Tiwari and Pinaki Majumdar, *Non-collinear Magnetic Order in the Double Perovskites: Double Exchange on a Geometrically Frustrated Lattice,* (in preparation).
3. Kalpataru Pradhan and Pinaki Majumdar, *B site Disorder on the Half-Doped Manganites: Effect of the Mn-B interactions*, (in preparation).
4. Kalpataru Pradhan and Pinaki Majumdar, *The Effects of B Site Doping on the Manganites: Valence Change and Percolation,* (in preparation).

Conference/Workshops Attended:

1. *I.I.Sc Physics Centenary Conference*, Bangalore, India, May 2009.
2. *Golden Jubilee Conference, IIT Kanpur*, Kanpur, India Jan-Feb 2010.

Visits to other Institutes:

1. IISc Bangalore, May 2009.

Invited Lectures/Seminars:

1. *Magnetism in the disordered double perovskite ferromagnets* , IISc Physics Centenary Conference, IISc Bangalore, May 2009.
2. *Phase diagram of the double perovskites*, IIT Kanpur, Feb 2010.

Other Activities:

1. Taught course on Condensed Matter Physics (autumn 2009) and Statistical Mechanics (spring 2010).
2. Coordinated and participated in the KVPY interviews, HRI, Jan 2010.
3. Organised the Indo-EU Collaboration Meeting on Computational Materials Science, HRI, Jan 2010.

Biswarup Mukhopadhyaya

In continuation of a series of studies on LHC signals of supersymmetry (SUSY) with non-universal high-scale conditions, a non-universal model answering to the dark matter content of the universe has been investigated. It has been shown the final states arising from the production of the top-and bottom-sqaurks can lead to viable multilepton signals at the LHC, and event selection criteria have been suggested. (Biswarup Mukhopadhyaya, Subhaditya Bhattacharya, Utpal Chattopadhyay, Debajyoti Choudhury and Debotam Das)

Various aspects of SUSY theories with a right-sneutrino dark matter candidates have been investigated for the LHC. Using the fact that such scenarios can lead to stable charged particles recorded by collider detectors, the possibility of neutralino and chargino mass reconstruction has been investigated. (Sanjoy Biswas andd Biswarup Mukhopadhyaya)

The role of baryon number violation in the resonant production of supersymmetric particles (especially the top-squark) at the LHC has been studied. An exhaustive set of criteria has been evolved in this context. (Nishita Desai and Biswarup Mukhopadhyaya)

Various new features of 5-dimensional Randall-Sundrum models with a nonvanishing brane cosmological constant have been pointed out. One of these is the demonstration that, with sterile neutrinos in the bulk, the explanation of neutrino data can be linked to the criteria for achieving a positive brane tension, i.e. stability of a 4-dimensionakl universe. Also, the possibility of accommodating a bulk Higgs field in such a scenario has been suggested. (Paramita dey, Biswarup Mukhopadhyaya, Soumitra SenGupta)

A model of neutrino mass generation, often linked with the inverse seesaw mechanism, which can lead to an observable loss of unitarity in the neutrino mixing matrix, has been formulated with one flat spacelike extra dimension. It is shown that, with gauge singlet neutrinos propagating in the bulk, this can lead to small lepton-number violating entries in the neutrino mass matrix, and cause unitarity loss to the tune of 1 per cent. (Subhaditya Bhattacharya, Paramita Dey, Biswarup Mukhopadhyaya)

Smoking gun signals of a little Higgs scenario, where T-parity is broken by the Wess-Zumino-WItten anomaly term, has been developed for the LHC. The usefulness of 2-and 4-lepton final states, and the role of conspicuous mass peaks even with limited luminosity, have been emphasized. (Biswarup Mukhopadhyaya, Satyanarayan Mukhopadhyay and Andreas Nyffeler)

An R-parity violating breaking supersymmetric theory which can explain the persistent μ-problem is studied with special reference to neutrino masses and mixing data. Detailed calculations reveal the important role of radiative mass generation mechanism side by side with TeV-scal seesaw. The relative strengths of the two mechanisms in the cases of normal hierarchy, inverted hierarchy and degenerate neutrinos have been thoroughly investigated.

(Paramita Dey, Biswarup Mukhopadhyaya, Pradipta Ghosh and Sourov Roy)

Publications:

1. Nishita Desai, Biswarup Mukhopadhya, *Signals of supersymmetry with inaccessible first two families at the Large Hadron Collider,* Phys. Rev. **D80**, 055019, (2009)
2. Sanjoy Biswas, Biswarup Mukhop, *Neutralino reconstruction in supersymmetry with long-lived staus,* Phys. Rev. **D79**, 115009, (2009)
3. Biswarup Mukhopadhyaya, Somasri Sen, Soumitra SenGupta, *A Randall-Sundrum scenario with bulk dilaton and torsion*, Phys. Rev. **D79**, 124029, (2009)
4. Paramita Dey, Biswarup Mukhopadhyaya, Soumitra SenGupta, *Neutrino masses, the cosmological constant and a stable universe in a Randall-Sundrum scenario*, Phys. Rev. **D80**, 055029, (2009)
5. Subhaditya Bhattacharya, Paramita Dey, Biswarup Mukhopadhyaya, *Unitarity violation in sequential neutrino mixing in a model of extra dimensions*, Phys. Rev. **D80**, 075013, (2009)
6. Subhaditya Bhattacharya, Utpal Chattopadhyay, Debajyoti Choudhury, Debottam Das, Biswarup Mukhopadhyaya, *Non-universal scalar mass scenario with Higgs funnel region of SUSY dark matter: A Signal-based analysis for the Large Hadron Collider*, Phys. Rev. **D81**, 075009, (2010)
7. Sanjoy Biswas, Biswarup Mukhopadhyaya, *Chargino reconstruction in supersymmetry with long-lived staus*, Phys. Rev. **D81**, 015003, (2010)
8. Paramita Dey, Biswarup Mukhopadhyaya, Soumitra SenGupta, *Bulk Higgs field in a Randall-Sundrum model with nonvanishing brane cosmological constant*, Phys. Rev. **D81**, 036011, (2010)
9. Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, Andreas Nyffeler, *Dilepton and Four-Lepton Signals at the LHC in the Littlest Higgs Model with T-parity Violation*, JHEP **1005**, 001, (2010)
10. Biswarup Mukhopadhyaya, P. Nath *et al.*, The Hunt for New Physics at the Large Hadron Collider, Nucl. Phys. Proc. Suppl. **200-202**, 185, (2010)
11. Pradipta Ghosh, Paramita Dey, Biswarup Mukhopadhyaya, Sourov Roy, *Radiative contribution to neutrino masses and mixing in $\mu\nu$SSM*, JHEP **1005**, 087, (2010)

Preprints:

1. Nishita Desai, Biswar, *R-parity violating resonant stop production at the Large Hadron Collider*, arXiv:1002.2339 [hep-ph]

Conference/Workshops Attended:

1. *SUSY-09*, Boston, Unites States of America, June, 2009,

2. *Beyond the Standard Model Physics and LHC Signatures (BSM-LHC)*, Boston, Unites States of America, June, 2009.
3. *New Physics and the LHC*, Mumbai, India, October, 2009.
4. *Physics beyond the standard model*, Kolkata, India, December, 2009.
5. *Data to theory at the LHC*, Shimla, India, December, 2009.

Visits to other Institutes:

1. Indian Institute of Science, Bangalore, India, April, 2009.
2. Northeastern University, Boston, USA, June, 2009
3. Tata Institute of Fundamental Research, Mumbai, India, October, 2009.
4. University of Calcutta, Kolkata, India, December, 2009.
5. Indian Institute of Advanced Study, Shimla, India, December, 2009.
6. S. N. Bose National Centre for Basic Sciences, Kolkata, India, March, 2009.
7. Indian Association for the Cultivation of Science, Kolkata, India, December, 2009 - May, 2010.

Invited Lectures/Seminars:

1. *The Large Hadron Collider: Quest for the visible and the invisible*, Physics Colloquium, Indian Institute of Science, Bangalore, April, 2009.
2. *Benchmarking non-universal SUSY through multchannel analysis at the LHC*, SUSY-09, Boston, USA, June, 2009.
3. *Supersymmetry with right-handed neutrinos and the LHC*, Invited talk, , BSM-LHC, Boston, USA, June, 2009.
4. *New physics and the LHC: The theorist's prejudice*, Keynote adress, BSM-LHC, tata Institute of Fundamental Research, Mumbai, October, 2009.
5. *Search for the Higgs boson and dark matter*, Invited talk, Outreach programme on the LHC, SCience City, Kolkata, October, 2009.
6. *The Higgs boson and the LHC*, Invited talk, Physics Beyond the Standard Model, University of Calcutta, Kolkata, December, 2009.
7. *The Physicist in Chains*, Invited seminar, Indian Institute of Advanced Study, Shimla, December, 2009.
8. *The Large hadron Collider: Some reflections on the visible and the invisible*, Colloquium, S. N. Bose National Centre for Basic Sciences, Kolkata, India, March, 2009.

Other Activities:

1. Served as Co-ordinator, Regional centre for Accelerator-based Particle Physics,HRI.
2. Completed a 3-years term as Dean, Academic at HRI.

Satchidananda Naik

Off-Shell Closed String Amplitude

as $\mathcal{N}$=8 Supergravity amplitudes in Twistor Space for Self-dual Closed String Fields

A closed string field theory action is formulated for the $\mathcal{N}$ = 8 self-dual supergravity which is off-shell and Lorentz covariant. The bosonic truncation in the quantum field theory limit gives the Plebanski action in the super space. In the On-shell limit only the three point function is possible. In the off-shell more than three point function is obtainable from where one can even get full Supergravity action starting from self-dual by sewing the self-dual with anti-selfdual part .

Preprints:

1. Satchidananda Naik, *Self-Dual $\mathcal{N}$=8 Supergravity*

   as a Closed String Field Theory in Twistor Space, hep-th - 0903.2872

Visits to other Institutes:

1. Institute of Physics ,Bhubaneswar From 11-7-09-22-7-09

invited Lectures/Seminars:

1. Closed String Field theory formulation of Self-dual Supergravity at IOP, Bhubaneswar

Courses Given:

1. Classical Mechanics

G. Venketeswara Pai

I am working on the problem of orbital ordering in insulating perovskite manganites with an emphasis on the role of ionic radii variations and doping. I have also started to explore the physics of time periodic spin-orbit coupling in mesoscopic systems.

Visits to other Institutes:

1. Department of Physics, Indian Institute of Science, Bangalore, March 2010.

Sudhakar Panda

We studied inflation driven by N dynamical five branes in Heterotic M-theory using the scalar potential derived from the open membrane instanton sector. Our analysis yeilds that at leading order, we can realize power law inflation but subleading corrections put constraints on the number N for inflation to occur.

We investigated the possibility of reheating the universe in a scenario of D-brane inflation in a warped deformed conifold background which includes perturbative corrections to throat geometry sourced by a chiral operator of dimension 3/2 in the dual conformal field theory. In this case, the effecive potential felt by a mobile D3-brane belongs to the class of non-oscillatory models of inflation. Thus the conventional reheating mechanism does not work. Further we find that the gravitational particle production is inefficient. On the contrary, we showed that instant preheating is very suitable to the present scenario and the reheating temperature is found to be in the order of 10^{11} Gev.

Publications:

1. Warm tachyonic inflation in warped background, (with A. Deshamukhya), **Int.J.Mod.Phys. D18 (2009) 2093**.

2. Higher Order Corrections to Heterotic M-theory inflation, (with P.V. Moniz and J.Ward), **Class. Quantum Grav. 26 (2009) 245003**.

Preprints:

1. Higher Order Corrections to Heterotic M-theory inflation, (with P.V. Moniz and J.Ward), **arXiv:0907.0711 [astro-ph.CO]**.

2. Reheating the D-brane universe via instant preheating, (with M.Sami and I.. Thongkool), **arXiv:0905.2284 [hep-th]**.

Conference/Workshops Attended:

1. *NSM-09 (National String Meeting, I.I.T. Bombay*, India, 2010.

2. *UGC- DRS Semina, Utkal University, Bhubaneswar*, India, 2010.

Visits to other Institutes:

1. Centre for Theoretical Physics, Univ. of Groningen, Groningen, The Netherlands, 2009.
2. KEK, Tsukuba, Japan, 2009.
3. RIKEN, Tokyo, Japan, 2009.

Invited Lectures/Seminars:

1. " Brane inflation and Moduli Stabilization" at **University of Groningen**, The Netherlands, (2009).
2. " Brane Inflation and Reheating" at **KEK, Tsukuba**, Japan, (2009).
3. " Inflation in the throat" at **RIKEN**, Japan, (2009).
4. " Searching for Unification" at **Assam University**, Silchar, India, (2010).
5. " An overview of String Cosmology" at **Utkal University**, Bhubaneswar, India, (2010).

Other Activities:

1. Dean, Administration, from May, 2009.
2. Convenor, Local Works Committee, 2009-10.
3. Member, Faculty Advisory Committee, 2009-10.
4. Member, Board of Studies, CTP, Jamia-Milia Univ, Delhi.
5. Convenor, Horticulture Committee, 2008-09.
6. Taught a course on Advanced Quantum Mechanics under HRI Ph.D. course program, January-May, 2009.
7. Taught a course on Quantum Field Theory-I under HRI Ph.D. course program, January-May, 2010.

Tribhuvan Prasad Pareek

I have focused on Quantum spin transport. The generally accepted transport for spin is classical in the sense that off diagonal elements of spin density matrix do not contribute to the standard charge transport measurement, since these are effectively spin blind. In other words the very processes of measurement destroys the spin coherence. Therefore one can treat the two states of spin as completely decohered (with out any phase coherence) hence the very intriguing question of what is "Quantum spin transport" and how can one devise of electrical means of detecting them.

We have been studying Quantum spin transport within scattering theory. We have developed a phenomenological theory of it. Further to put it on more stronger foundation we developed a unified description of "Quantum spin and charge transport" using Quaternionic formulation. From this analysis it becomes clear that spin Quantum spin transport is essentially a Topological quantity- in a sense that deformation of Bloch sphere are relation to Quantum spin currents hence the standard charge current measurement are in some sense in complete measurement of spin currents. Infact this very process makes them classical. Towards this ens we are further developing theoretical methods and simultaneously also looking at new measurement schemes to detect quantum spin transport.

Preprints:

1. T. P. Pareek, *Multi-terminal Spin Transport: Non applicability of linear response and Equilibrium spin currents,* arXiv:Cond-mat/0809.5119
2. T.P. Pareek, *Unified quaternionic description of chargeand spin transport and intrinsic non-linearity of spin currents"*, arXiv:Cond-mat/1002.3961

Conference/Workshops Attended:

1. *"Homi Bhabha Centenary DAE-BRNS National conference and School on Spintronic and Magneto electronic Materials and Devices"*,India, January 2009.
2. *"Indo-French Seminar on Magnetic Materials and Spintronics (IFCPAR)", Varanasi, from January 28 to 31, 2010.*

Visits to other Institutes:

1. IOP, Bhubaneswar, India, January 2009.

Invited Lectures/Seminars:

1. *Spin transport in nano-systems(2 lectures)*, "Homi Bhabha Centenary DAE-BRNS National conference and School on Spintronic and Magneto electronic Materials and Devices", PURI, January 2009.

2. *Spin Polarized Transport in Multiterminal Systems: Indo French Seminar(IFCPAR) on "Maganetic Materials and Spintronics", Varanasi, January 2010.*

Other Activities:

1. I organized "Homi Bhabha Centenary DAE-BRNS National conference and School on Spintronic and Magneto electronic Materials and Devices" from January 5-7, 2009. The venue of the conference cum school was Toshali sand, Puri. The school preceded the conference and around 40 students participated in the school cum conference. The school was aimed at introducing the youngster to the emerging field of spintronics and magneto-electronic.
   I have taught Advanced cond mat course in our graduate programme. I am member od various administrative committees of the institute.
2. Three visiting students did their summer project with me during last year. One of the student -Peayush Choubey from ISM Dhanbad who worked on Quantum spin transport has been selected for PH. D. Programme in various foreign universities.

Sumathi Rao

During the period, April 2009 - March 2010, I worked on tunneling density of states and spin polarised scanning tunneling microscopy in Tomonaga-Luttinger liquid wires and transport through superconductor-normal wire and superconductor-graphene junctions.

For a three-wire junction, we showed that there are fixed points which allow for the *enhancement* of the tunneling density of states which is unusual for Luttinger liquids.

In contrast to the standard stub geometry which has both transmission resonances and anti-resonances in the coherent limit, we show that when the stub is connected to a superconductor, the transmission across the wire shows only resonances at $T = 1/4$, where charge transport vanishes while the spin transport is perfect.

We studied resonant transport through a superconducting double barrier structure. At each barrier, due to the proximity effect, an incident electron can either reflect or transmit as an electron or a hole (Andreev reflection). In the subgap regime, for a symmetric double barrier system, we find a new $T = 1/4$ resonance due to interference between electron and hole wave-functions between the two barriers, in contrast to a normal double barrier system which has the standard transmission resonance at $T = 1$, which can produce pure spin current through the superconducting double barrier structure. We have also generalised this to the case when the superconducting double barrier tunneling is through a graphene sheet, which adds other features like specular and retro Andreev reflection depending on the angle of incidence. Here, we find resonant suppression of Andreev reflection at some energies, where the transmission probability T for electrons incident on the double barrier structure becomes unity, which is due to the formation of Andreev bound levels between the two barriers.

We proposed a three terminal setup based on spin polarised scanning tunneling microscopy for probing the helical nature of the Luttinger liquid edges appearing in quantum spin Hall systems and showed that the injection of spin polarised electrons via a magnetic STM tip into the helical Luttinger liquid leads to the appearance of an asymmetry between the voltages and the spin currents at the two ends of the helical Luttinger liquid.

Publications:

1. Amit Agarwal, Sourin Das, Sumathi Rao and Diptiman Sen, *Enhancement of tunneling density of states at a junction of three Luttinger liquid wires*, cond-mat/0810.3513, Phys. Rev. Lett.**103**, 026401 (2009); erratum, *ibid* 079903(2009).
2. Sourin Das, Sumathi Rao and Arijit Saha, *Resonant transmission of pure spin current through a t-stub coupled to a superconductor* , cond-mat/0811.0660,

Europhys. Lett.**B72**, 139 (2009).
3. Arijit Kundu, Arijit Saha and Sumathi Rao, *Resonant spin transport through a superconducting double barrier structure*, cond-mat 0906. 3679, Europhys. Lett. **88**, 57003 (2009).

Preprints in progress:

1. Sourin Das and Sumathi Rao *Spin polarised scanning tunneling microscopy of helical Luttinger liquids*
2. Arijit Kundu, Sumathi Rao and Arijit Saha, *Resonant tunneling through superconducting double barrier structures in graphene*

Conferences/Workshops attended:

1. Mini-school on Topological Insulators and Quantum Spin-Hall effect, Ecole Normale Superiore, Lyon, France, Dec 9-11, 2009.
2. 'Science without boundaries', International centre for theoretical studies, Bangalore, Dec 28-31,2009

Visits to other Institutes:

1. CHEP, Indian Institute of Science, Bangalore, July 2009
2. On sabbatical at LPTHE and LPTMC, University of Paris, Jussieu, Sept 15, 2009 - Sept 15, 2010
3. Dept of Physics, University of Utrecht, March 10-15, 2010

Invited Lectures/Seminars:

1. *Resonant spin and charge transport through a superconducting double barrier structure*, CHEP, Bangalore, July 1, 2009
2. *Fun with quantum mechanics or resonant spin and charge transport through a superconducting double barrier structure*, LPTHE, University of Pierre and Marie Curie, Jussieu, Paris VI, October 8, 2009
3. *Colloquium on Luttinger liquids, Dept. of Physics, Utrecht University, March 10, 2010*

Other Activities:

1. Taught *quantum field theory I* , Jan-May 2009.
2. Convenor, Local works committee (till August 2009).
3. Convenor, Women's grievance cell (till August 2009).
4. Member, Faculty Advisory committee and Budget committee (till August 2009).
5. Member, Board of Studies, School of Physics, Jawaharlal Nehru University, New Delhi (till August 2009).

V. Ravindran

Models with large extra dimensions not only address the heirachy problem but also predict observables that are accessible at colliders such as Tevatron at Fermi-lab and Large Hadron Collider (LHC) at CERN. There are already several intensive studies in this direction in order to test these models. These studies have been mostly at the Born level in Quantum Chromodynamics (QCD). Since the next to leading order (NLO) QCD effects to the Born contributions play important role in order to quantify the size of the effects and to see how robust the leading order estimate of the cross-section is with respect to these corrections. In addition, these corrections reduce various theoretical uncertainties arising from missing higher order quantum corrections through renormalisation and factorisation scales. We have obtained the first results on next-to-leading order QCD corrections to the production of pair of vector bosons such as ZZ and W^+W^- in hadronic collisions in the large extra dimension ADD model and also extended our analysis to RS model. For these processes, various kinematical distributions are studied to order α_s in QCD by taking into account all the parton level subprocesses. We estimated the impact of the QCD corrections on various observables and found to be significant. We have also showed the reduction in factorisation scale uncertainty when $\mathcal{O}(\alpha_s)$ effects are included.

Publications:

1. N. Agarwal, V. Ravindran, V. K. Tiwari and A. Tripathi, *Next-to-leading order QCD corrections to the Z boson pair production at the LHC in Randall Sundrum model,* Phys. Lett. B **686** 244 (2010) [arXiv:0910.1551 [hep-ph]].
2. N. Agarwal, V. Ravindran, V. K. Tiwari and A. Tripathi, *Z boson pair production at the LHC to $\mathcal{O}(\alpha_s)$ in TeV scale gravity models,* Nucl. Phys. B **830** 248 (2010) [arXiv:0909.2651 [hep-ph]].
3. A. Mukherjee *et al., Working group report: Quantum chromodynamics subgroup,* Pramana **72** 277 (2009).

Preprints:

1. N. Agarwal, V. Ravindran, V. K. Tiwari and A. Tripathi, *W^+W^- production in Large extra dimension model at next-to-leading order in QCD at the LHC,* arXiv:1003.5450 [hep-ph].
2. N. Agarwal, V. Ravindran, V. K. Tiwari and A. Tripathi, *Next-to-leading order QCD corrections to W^+W^- production at the LHC in Randall Sundrum model,* arXiv:1003.5445 [hep-ph].

Conference/Workshops Attended:

1. "9th International Symposium on Radiative Corrections, RADCOR 2009 conferecne in Ascona, Switzerland from 24th-31st October 2009,

2. WORKSHOP ON HIGH ENERGY PHYSICS PHENOMENOLOGY (WHEPP XI) , Physical Research Laboratory, Ahmedabad, 2 - 12th January 2010

Visits to other Institutes:

1. Institute of Mathematical Sciences, Chennai, June 1-7,2009.
2. Laboratoire d'Annecy-le-Vieux de Physique Thorique(LAPTH)-9 Chemin Bellevue-BP 110 74941 Annecy de Vieux cedex, Centre National de la Recherche Scientifique, France from 1st to 30th November 2009
3. Theory group, CERN, Organisation Europeenne Pour La Recherche Nucleaire, European Organization for Nuclear Research at Geneva, Switzerland from 30th-November to 13th December 2009.

Invited Lectures/Seminars:

1. *Soft gluon resummation for Higgs production at the LHC*, Institute of Mathematical Sciences, Chennai, 4th June ,2009.
2. *Soft and Collinear gluon corrections to Higgs production beyond two loop*, RADCOR 2009, Centro Stefano Franscini, Ascona, October, 2009.
3. *Soft gluon contributions to Higgs production at LHC beyond two loops* , LAPTh,Annecy, November 2009

Other Activities:

1. Taught a semester course on "Mathematical Methods-II" to graduate students of HRI.
2. Coordinator of working Group, "Physics at LHC", WORKSHOP ON HIGH ENERGY PHYSICS PHENOMENOLOGY (WHEPP XI) , Physical Research Laboratory, Ahmedabad, 2 - 12th January 2010

Amitava Raychaudhuri

During 2009-10 research has been focussed on extra-dimensional models and grand unified theories.

Simplest universal extra-dimensional models assume that the quarks, leptons, gauge bosons, and Higgs scalars all live in a five-dimensional world. The fifth spacelike dimension is compact on a scale which is too small for experimental verification till now. When viewed from a four-dimensional perspective, the compact nature of this extra dimension results in a tower of excitations of the known particles – Kaluza-Klein states – whose masses may well be in the range of the LHC. In a recent investigation a detailed analysis has been carried out for the production of excited quarks and gauge bosons at the LHC and their detectability.

In grand unified theories, some effects of quantum gravity can be captured through the introduction of gauge invariant dimension-5 operators suppressed by the Planck mass. A class of such operators can influence the unification of coupling constants leading to intermediate scales which may be detectable through neutron-antineutron oscillations or even through the production of new gauge bosons. This has been studied in the context of SO(10) and E(6) GUTs.

Publications:

1. Gautam Bhattacharyya, Anindya Datta, Swarup Kumar Majee, and Amitava Raychaudhuri, *Exploring the Universal Extra Dimension at the CERN LHC,* Nucl. Phys. **B821,** 48-64 (2009).
2. Joydeep Chakrabortty and Amitava Raychaudhuri, *GUTs with dim-5 interactions: Gauge Unification and Intermediate Scales,* Phys. Rev. **D81,** 055004 (2010).
3. Amitava Raychaudhuri, *Nuances of Neutrinos*, in 'Recent Developments in Theoretical Physics', Subir Ghosh and Guruprasad Kar (eds.). World Scientific (2010). *(Conference proceedings)*
4. Amitava Raychaudhuri, *How subatomic particles interact*, in 'Flavors of Research in Physics', Utpal Sarkar (ed.) (2010). *(Popular article)*
5. Amitava Datta, Biswarup Mukhopadhyaya, and Amitava Raychaudhuri (eds.), Physics at the Large Hadron Collider (Special Volume to mark the Platinum Jubilee of the Indian National Science Academy), Springer, Delhi (2009).

Conference/Workshops Attended:

1. *WHEPP XI*, Physical Research Laboratory, Ahmedabad, January 2010.
2. *LHC and the New Frontiers of Particle Physics*, Calcutta University, Kolkata, December 2009.

3. *Science & Technology at the Frontiers, Bhabha Centenary Symposium*, Tata Institute of Fundamental Research, Mumbai, December 2009.
4. *INSA Platinum Jubilee Symposium*, Saha Institute of Nuclear Physics, Kolkata, December 2009.
5. *Neutrinos in the LHC Era*, Luxor, Egypt, November 2009.

Invited Lectures/Seminars:

1. *What is Leptogenesis?*, LHC and the New Frontiers of Particle Physics, Calcutta University, Kolkata, December 2009.
2. *Exploring neutrino parameters with a magical beta-beam experiment*, Neutrinos in the LHC Era, Luxor, Egypt, November 2009.
3. *A low energy probe of Nature's Building Blocks: Neutrino Novelties*, Institute Colloquium, Indian Institute of Technology Bombay, Mumbai, March 2010.

Ashoke Sen

My research during the period April 2009 - March 2010 focussed mainly on understanding black hole entropy in string theory. The main thrust of my research was to investigate how the quantum entropy function approach, proposed earlier for computing quantum correction to the black hole entropy, can be used to explain various aspects of the exact microscopic results for the black hole entropy in $N = 4$ supersymmetric string theories. To this end I showed that various non-perturbative features of the microscopic entropy can be explained using the quantum entropy function approach. This was also generalized to make prediction on the twisted index that couts not the total number of states but a weighted sum of the total number of states. This was verified in microscopic analysis, thereby providing strong support for the quantum entropy function proposal. Together with Nabamita Banerjee, Shamik Banerjee, Rajesh Gupta and Ipsita Mandal I also showed how supersymmetry and localization methods can be used to simplify the path integral over the string fields which enter the computation of the quantum entropy function. This was used to derive some general results on the quantum entropy function.

Another aspect of my research on black holes involved analysis of the hair modes, – modes which live outside the horizon and yet can contribute to the total entropy. In my paper with Dileep Jatkar and Yogesh Srivastava I analyzed the hair modes of a specific class of black holes and showed how they are important in relating the microscopic and the macroscopic entropies. I also extended this general understanding of the hair modes to the analysis of small black holes, – black holes whose event horizon vanishes in the gravity approximation but gets a finite value when stringy corrections are included. For this system I showed that the system may have different descriptions in different duality frames, *e.g.* as a black hole in one frame and as a family of smooth solutions in another frame.

Publications:

1. N. Banerjee, S. Banerjee, R. K. Gupta, I. Mandal and A. Sen, "Supersymmetry, Localization and Quantum Entropy Function," JHEP **1002**, 091 (2010) [arXiv:0905.2686 [hep-th]].
2. D. P. Jatkar, A. Sen and Y. K. Srivastava, "Black Hole Hair Removal: Non-linear Analysis," JHEP **1002**, 038 (2010) [arXiv:0907.0593 [hep-th]].
3. A. Sen, "Arithmetic of N=8 Black Holes," JHEP **1002**, 090 (2010) [arXiv:0908.0039 [hep-th]].
4. A. Sen, "Two Charge System Revisited: Small Black Holes or Horizonless Solutions?," arXiv:0908.3402 [hep-th].
5. A. Sen, "A Twist in the Dyon Partition Function," arXiv:0911.1563 [hep-th].
6. A. Sen, "Discrete Information from CHL Black Holes," arXiv:1002.3857 [hep-th].

Invited Lectures/Seminars at Schools/Conferences:

1. IPM string school, April 9-18, 2009.
2. 4th School On Attractor Mechanism: SAM 2009, 29 Jun - 3 Jul 2009, Frascati, Italy.
3. Strings 2009, 22-26 June 2009, Rome, Italy.
4. PASCOS 2009, 6-10 July 2009, Hamburg, Germany.
5. 12th Marcel Grossmann Meeting On General Relativity (MG 12), 12-18 Jul 2009, Paris, France.
6. Iberian Strings 2010, 10-12 Feb 2010, Porto, Portugal.
7. Strings 2010, 15-19 Mar 2010, College Station, Texas.

Courses given:

1. Statistical Mechanics, January - May, 2009.
2. Quantum black holes (together with Atish Dabholkar at LPTHE, Paris, France), February - April, 2010.

Prasenjit Sen

Major focus of my research this year has been on atomic clusters. We explored Sc doped alkali clusters and proposed ways in which the magnetic moment on Sc-(alkali)$_{12}$ clusters can be tuned by choosing the appropriate alkali atom. We also explored Ti-alkali clusters in greater detail. We showed that filling of both delocalized electronic shells, and atomic d shells on the Ti atom leads to enhanced stability of clusters. This was the first demonstration of enhanced cluster stability due to half-filled atomic-like d shells. These findings can lead to identification of stable cluster motifs with potential for varied applications.

There was a debate as to whether various electron-counting rules can explain relative stability of transition metal (TM) encapsulated Si or Ge cage clusters. In this context it was claimed that a nearly free-electron gas is formed inside a Si cage encapsulating a TM atom. We addressed the same question in case of Ni encapsulated Ge clusters. Indeed, it turns out that clusters having 20 valence electrons have enhanced stability, as predicted in a free-electron model. Further analysis of this issue is going on.

I also worked on solid surfaces and bulk solid systems. Possible formation of Au chains on different hydrogenated Si(001) surface was explored using density functional theory (DFT) methods. We explored unusual magnetism in alkali oxide materials KO_2. While DFT and more accurate quantum Monte Carlo (QMC) methods predict this material to have a magnetic ground state with a large transition temperature, experiments found a weak signature of antiferromagnetism at as low as 7 K. A deeper exploration of this paradox led us to the understanding that KO_2 has an orbital ordered (OO) ground state which leads to many competing magnetic ground states. This is the first example of an OO state in a p-orbital material.

Publications:

1. K. Pradhan, J. U. Reveles, P. Sen and S. N. Khanna, *Enhanced magnetic moments of alkali metal coated Sc clusters,* J Chem. Phys. **132**, 124302, (2010)
2. P. Sen, *Density functional study of ferromagnetism in alkali metal thin films,* Pramana J Phys. **74**, 653, (2010)
3. D. Bandyopadhyay and P. Sen, *Density functional investigation of structure and stability of Ge_n and Ge_nNi (n =1-20) clusters: Validity of Electron Counting Rule,* J Phys. Chem. A **114**, 1835, (2010)
4. S. Konar, B. C. Gupta and P. Sen, *Stable gold chain on hydrogen terminated Si(001):(3×1) surface: A density functional study,* J Appl. Phys. **106**, 093712, (2009)

Preprints:

1. P. Sen, *Electronic shells and magnetism in small metal clusters*, Chapter in the book "Aromaticity and Metal Clusters", CRC Press, Ed. P. K. Chattaraj

(in press).
2. J. U. Reveles, P. Sen, K. Pradhan, D. R. Roy and S. N. Khanna, *Effect of electronic and geometric shell closures on the stability of neutral and anionic $TiNa_n$ (n=1-13) clusters,* (under review).
3. A. Nandy, P. Mahadevan, P. Sen and D. D. Sharma, *KO_2: Realization of orbital ordering in a p-orbital system,* (in preparation).

Conference/Workshops Attended:

1. *International Workshop on Frontiers of Electronic Structure Calculations: Techniques and Applications*, India, February, 2010.
2. *Statistical and Condensed Matter Physics*, India, October-November, 2009.
3. *One Day National Symposium in Theoretical Sciences*, India, December, 2009.
4. *Of Molecules and Materials*, India, December, 2009.

Visits to other Institutes:

1. Virginia Commonwealth University, Richmond VA, USA, August-September, 2009.
2. Indian Institute of Technology, Guwahati, India, October-November, 2009.
3. Indian Institute Science Education and Research, Kolkata, India, December, 2009.
4. Indian Institute of Technology, Kharagpur, India, December, 2009.
5. University of Pune, Pune, India, February, 2010.

Invited Lectures/Seminars:

1. *Electron Counting Rules in Atomic Clusters: Applicability and consequences*, One Day National Symposium in Theoretical Sciences, IIT, Kharagpur, December, 2009..
2. *Transition metal doped alkali clusters: Simple systems with far-reaching consequences*, Statistical and Condensed Matter Physics, IIT, Guwahati, October-November, 2009.
3. *Stability of transition metal-alkali metal clusters: Causes and consequences*, International Workshop on Frontiers of Electronic Structure Calculations: Techniques and Applications, University of Pune, Pune, February, 2010.

Other Activities:

1. Reviewed manuscripts for the journals *Physical Review B*, *Physical Review Letters* and *Applied Physics Letters*.
2. Organized the International Symposium Of Molecules and Materials as member of the National Organizing Committee.
3. Acted as the nodal person at HRI for the Garuda Grid throughout the year.

4. Taught a course on Advanced Condensed Matter Physics.
5. Mentored visiting undergraduate (VSP) and graduate students.

Ujjwal Sen

My area of research is quantum information and computation, and the several connections of this subject with the other sciences. There has been two main themes of my research in the academic year 2009-2010: (a) Capacities of multi-port quantum channels; (b) Using quantum information concepts to solve many-body physics problems.

Understanding quantum entanglement has been one of the key features in the development of the science of quantum information. Applications of quantum information had started off in the fields of communication, cryptography, computation, and thermodynamics, and has since diffused into diverse areas such as condensed matter physics, ultra-cold gases, and statistical mechanics. Measuring and detecting entanglement of the quantum states appearing in different physical situations has been the cornerstones of the development in these directions. It has therefore been very important to propose entanglement measures of quantum states of systems consisting of more than one subsystem, and there is a flourishing industry of such proposals. However, the main progress in the theory of entanglement measures, and its detection, has been in the case when the physical system consists of only two subsystems. This has been a major handicap in using entanglement as an instrument for handling many-body physics systems like ultra-cold atomic states, where the majority, if not all, of the quantum states involved are of multiparty systems, i.e. a physical system consisting of more than two subsystems. Understanding multiparty quantum entanglement is therefore a distinct necessity to a large portion of physics of our times. In an attempt to at least partially fill this gap, we have defined a measure of genuine multiparty entanglement, that is computable for multiparty pure quantum states of an arbitrary number of parties in arbitrary dimensions. We have called it the generalized geometric measure.

We have used this entanglement measure in two different physical situations.

(a) To investigate the connection of multi-port quantum channel capacities with genuine multi-party entanglement. Multi-port classical channels are useful resources in classical communication networks. Likewise, multi-port quantum channels are the prime resources with which a commercially viable quantum communication network can potentially be built. Such quantum networks are known to outperform their classical counterparts.

(b) To differentiate gapless phases from gapped ones in frustrated quantum many-body systems. Frustrated many-body systems are one of the center-stages of research in many-body physics. They are, for example, potentially important for understanding high-Tc superconductivity.

Entanglement mean field theory. Recently, we have also presented a method for solving many-body physics Hamiltonians, which is a natural generaliza-

tion of the mean field theory (MFT) initiated by P. Weiss in 1907. While the MFT reduces the many-body Hamiltonian to one with a single particle, the entanglement mean field theory (EMFT) reduces it to a two-body one. While MFT is an important method for approximate descriptions of single-body physical parameters like magnetization, EMFT can be used to approximately calculate two-body physical parameters like correlations and entanglement.

Publications:

1. Aditi Sen (De), and Ujjwal Sen, *Channel capacities versus entanglement measures in multiparty quantum states*, Phys. Rev. A **81**, 012308, (2010).

Preprints:

1. Aditi Sen (De) and Ujjwal Sen, *Entanglement Mean Field Theory and the Curie-Weiss Law*, arXiv:0911.4856.
2. Aditi Sen (De) and Ujjwal Sen, *Bound Genuine Multisite Entanglement: Detector of Gapless-Gapped Quantum Transitions in Frustrated Systems*, arXiv:1002.1253.

Conference/Workshops Attended:

1. *International Conference on Cold Ions and Atoms 2010*, India, January, 2010.
2. *International Program on Quantum Information (IPQI-2010)*, India, January, 2010.

Invited Lectures/Seminars:

1. *Towards ultimate security in cryptography*, Invited talk in International Program on Quantum Information (IPQI-2010), Institute of Physics, and International Centre for Theoretical Sciences, held at Bhubaneswar, January, 2010.

Other Activities:

1. Gave a course (40 lectures) on "Advanced Quantum Mechanics" to HRI second-semester graduate students. January-May, 2010.
2. Guided a group of four HRI second-semester graduate students (Shrobona Bagchi, Abhishek Choudhury, Avijit Misra, Swapnamay Mondal) in a reading course, entitled "Classical simulation of quantum many-body systems." January-May, 2010.
3. Served as a referee for Physical Review Letters, Physical Review A, Physics Letters A, Pramana.
4. Member of the Computer Committee at HRI. From August, 2009.

L. Sriramkumar

During the last year, my research work was focused on investigating issues in the following two topics:

- Deviations from slow roll inflation and features in the primordial spectrum
- Low energy effects of quantum gravity

I have been analyzing the issues on inflationary cosmology along with my graduate student Rajeev Kumar Jain. I have briefly described below an issue each that I have studied in the two topics listed above.

The tensor-to-scalar ratio in punctuated inflation: Earlier, we had shown that scalar spectra with lower power on large scales and certain other features naturally occur in *punctuated inflation*, i.e. the scenario wherein a brief period of rapid roll is sandwiched between two stages of slow roll inflation. Such spectra gain importance due to the fact that they can lead to a better fit of the observed Cosmic Microwave Background (CMB) anisotropies, when compared to the conventional, featureless, power law spectrum. In this work, with examples from the canonical scalar field as well as the tachyonic models, we illustrate that, in punctuated inflation, a drop in the scalar power on large scales is *always* accompanied by a rise in the tensor power and, hence, an even more pronounced increase in the tensor-to-scalar ratio r on these scales. Interestingly, we find that r actually *exceeds well beyond unity* over a small range of scales. *To our knowledge, this work presents for the first time, examples of single scalar field inflationary models wherein* $r \gg 1$. This feature opens up interesting possibilities. For instance, we show that the rise in r on large scales translates to a rapid increase in the angular power spectrum, $C_\ell^{\rm BB}$, of the B-mode polarization of the CMB at the low multipoles.

Duality modified propagators in spacetimes with constant curvature: The hypothesis of path integral duality provides a prescription to evaluate the propagator of a free, quantum scalar field in a given classical background, taking into account the existence of a fundamental length, say, the Planck length, $L_{\rm P}$, in a *locally Lorentz invariant manner*. We use this prescription to evaluate the duality modified propagators in spacetimes with *constant curvature* (exactly in the case of one spacetime, and in the Gaussian approximation for another two), and show that: (i) the modified propagators are ultra violet finite, (ii) the modifications are *non-perturbative* in $L_{\rm P}$, and (iii) $L_{\rm P}$ seems to behave like a 'zero point length' of spacetime intervals such that $\langle \sigma^2(x,x') \rangle = \left[\sigma^2(x,x') + \mathcal{O}(1)\, L_{\rm P}^2\right]$, where $\sigma(x,x')$ is the geodesic distance between the two spacetime points x and x', and the angular brackets denote (a suitable) average over the quantum gravitational fluctuations.

Publications:

1. D. A. Kothawala, **L. Sriramkumar**, S. Shankaranarayanan and T. Padmanabhan, *Path integral duality modified propagators in spacetimes with constant curvature*, Phys. Rev. D **80**, 044005 (2009).
2. **L. Sriramkumar**, *An introduction to inflation and cosmological perturbation theory*, Curr. Sci. **97**, 868 (2009).

Preprints:

1. R. K. Jain, P. Chingangbam, **L. Sriramkumar** and T. Souradeep, *The tensor-to-scalar ratio in punctuated inflation*, arXiv:0904.2518v1 [astro-ph.CO].
2. S. Unnikrishnan and **L. Sriramkumar**, *A note on perfect scalar fields*, arXiv:1002.0820v1 [astro-ph.CO].
3. D. A. Kothawala, S. Shankaranarayanan and **L. Sriramkumar**, *Quantum gravitational corrections to the propagator in spacetimes with constant curvature*, arXiv:1002.1132v1 [hep-th], To appear in Proceedings of the Twelfth Marcel Grossmann Meeting on General Relativity.

Conferences/Workshops Attended:

1. *Neutrinos in Particle Astrophysics and Cosmology*, Chennai, India, April 5–7, 2009.
2. *Gravitation and Astronomy: Frontiers in Theory and Observations—The First IUCAA Reunion Meeting*, Inter-University Centre for Astronomy and Astrophysics, Pune, India, August 11–14, 2009.
3. *Indo-South African Workshop on Cosmology*, Inter-University Centre for Astronomy and Astrophysics, Pune, India, December 7-10, 2009.
4. *Cosmological Reionization*, Harish-Chandra Research Institute, Allahabad, India, February 16–20, 2010.

Visits to other Institutes:

1. Institut d'Astrophysique de Paris, Paris, France, October 9–November 7, 2009.

Invited Lectures/Seminars:

1. *Do primordial features have a future?*, Invited talk in *Neutrinos in Particle Astrophysics and Cosmology*, Chennai, India, April 5–7, 2009.
2. *Path integral duality, modified propagators and Planck scale effects*, in *Gravitation and Astronomy: Frontiers in Theory and Observations—The First IUCAA Reunion Meeting*, Inter-University Centre for Astronomy and Astrophysics, Pune, India, August 11–14, 2009.
3. *Punctuated inflation and the low CMB multipoles*, Seminar at Institut d'Astrophysique de Paris, Paris, France, October 19, 2009.

4. *A glimpse into the future of primordial features*, Invited talk in *Indo-South African Workshop on Cosmology*, Inter-University Centre for Astronomy and Astrophysics, Pune, India, December 7-10, 2009.

Other Activities:

1. I supervised the following students on summer projects:
   (a) Nilanjan Banik, B.Tech. Mechanical Engineering, III year, Department of Mechanical Engineering and Mining Machinery Engineering, Indian School of Mines, Dhanbad, India, May–June 2009.
   (b) Harikrishnan Ramani, B.Sc. Physics, II year, Chennai Mathematical Institute, Chennai, India, July 2009.
2. I taught a full-semester course on *General Theory of Relativity* to physics graduate students at HRI during August–December 2009.
3. I was a member of the Scientific Organizing Committee of the *Gravitation and Astronomy: Frontiers in Theory and Observations—The First IUCAA Reunion Meeting* that was held at the Inter-University Centre for Astronomy and Astrophysics, Pune, India, during August 11–14, 2009. I was also the coordinator of the session on *Quantum Aspects of Gravity and Early Universe* at the meeting.
4. I was incharge of conducting (the Physics part of) the HRI Science Talent Test 2009.
5. I supervised the following student on a first degree thesis: Atul Chhotray, Integrated M.Sc. in Physics and B.E. in Electrical and Electronics Engineering, V year, Birla Institute of Technology and Science, Pilani, India, January–May 2010.

Ram Lal Awasthi

Standard Model(SM) was one of the legendary steps in the direction of unification of fundamental interactions. It unifies strong, weak and electromagnetic interaction using the theory based on gauge group $SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$. It explains the behavior of fundamental interaction very precisely and has been verified by several experiments to a high level of accuracy. Still it's not a complete story. There are several evidences (explained/unexplained) leading us to consider a theory beyond SM. Grand Unification Theories(GUTs) are one way to explain the unification, using a simple group. The first attempt to GUT was minimal SU(5) model by Georgi and Glashow, with several short-comings, which have been tried to remove by extensions of the minimal SU(5). There are models based on other simple groups like SO(10). Their supersymmertric(SUSY) extensions also have been widely studied.

In this academic year I have been studying the basics of GUTs and SUSY. I, also, have been working on SUSY extension of SU(5) theory with additional 24_F and $15_H + \overline{15}_H$ representations(reps). We know that SU(5) GUT doesn't unify. SUSY extension of theory, though unifies, assumes neutrinos to be massless. Addition of a single 24_F(Adjoint) rep of SU(5) to the minimal model explains neutrino mass and mixing. It also gives some phenomenology at TeV scale, but we observed that SUSY extension of the model doesn't work. Considering the serious issue of mass hierarchy, we better supersymmetrise the theory. Hence we considered SUSY extension of Adjoint SU(5) with additional $15_H + \overline{15}_H$ multiplets. This gives gauge coupling unification, explanation to neutrino masses and mixing within the experimental constraints. We are also looking for richer phenomenology that might be present in this model.

Preprints:

1. Ram Lal Awasthi, Sandhya Choubey, Manimala Mitra (*in preparation*)

Conference/Workshops Attended:

1. *Nu-Horizones III*, Harish-Chandra Research Institute, Allahabad, India, Feb 08-10, 2010
2. *THEP-SERC School 2010*, Dept. of Physics, Panjab University, Chandigarh, India, April 02-22, 2010

Arjun Bagchi

My research over the past academic year has been directed at understanding the non-relativistic limit of the AdS/CFT correspondence through a method of group contraction initiated by Rajesh Gopakumar and myself last year. We have looked at supersymmetric extensions of the bosonic algebra called the Galilean Conformal Algebra (GCA) which was obtained as the non-relativistic limit of the relativistic conformal algebra. Here we found that like in the bosonic case, we could give an infinite dimensional lift to the super-algebra.

In another piece of work, we explored the GCA in the special case of two dimensions and looked at its quantum aspects. The analysis was carried out in two independent ways: answers were obtained by doing an analysis in the intrinsic non-relativistic way and then the same were reproduced from the relativistic answers by taking a systematic limit. Various novel answers for the non-relativistic conformal systems were obtained in this work.

We are at present looking at various other possible directions of work in the context of non-relativistic AdS/CFT.

Publications:

1. A. Bagchi and I. Mandal, *Supersymmetric Extension of Galilean Conformal Algebras,*
   Phys. Rev. D **80**, 086011 (2009) [arXiv:0905.0580 [hep-th]].

Preprints:

1. A. Bagchi, R. Gopakumar, I. Mandal and A. Miwa, *GCA in 2d,*
   arXiv:0912.1090 [hep-th].
2. A. Bagchi, R. Gopakumar, *Non-relativistic AdS/CFT and the GCA,*
   (Conference Proceedings: Sixth International Symposium on Quantum Theory and Symmetries, Kentucky, USA 2009.)
   (to be published in Journal of Physics: Conference Series)

Conference/Workshops Attended:

1. *Fourth Asian String School*, Mahabaleswar, January 2010
2. *National Strings Meet*, Mumbai, February 2010.

Visits to other Institutes:

1. State University of New York, Stony Brook, USA, October 2009.
2. University of Pennsylvania, Philadelphia, USA, October 2009.
3. Massachusetts Institute of Technology, Boston, USA, October 2009.
4. University of Washington, Seattle, USA, October 2009.

5. University of California, Santa Barbara, USA, October 2009.
6. Stanford University, USA, October 2009.
7. University of Chicago, USA, November 2009.
8. University of Michigan, Ann Arbor, USA, November 2009.
9. Cornell University, Ithaca, USA, November 2009.
10. Perimeter Institute for Theoretical Physics, Canada, November 2009.

Invited Lectures/Seminars:

1. *The Non-Relativistic Limit of AdS/CFT*,
   - YITP, Stony Brook, USA (Oct 2009)
   - University of Pennsylvania, USA (Oct 2009)
   - MIT, USA (Oct 2009)
   - University of Washington, Seattle, USA (Oct 2009)
   - Brown University, USA (Oct 2009)
   - KITP, Santa Barbara, USA (Oct 2009)
   - Stanford University, USA (Oct 2009)
   - University of Chicago, USA (Nov 2009)
   - University of Illinois, Chicago, USA (Nov 2009)
   - University of Michigan, USA (Nov 2009)
   - Cornell University, USA (Nov 2009)
   - Perimeter Institute, Canada (Nov 2009)
   - TIFR, India (Dec 2009)
2. *The Little Yellow Book*, National Strings Meet, IIT Powai, Mumbai, (Feb 2010)

Shamik Banerjee

I am a graduate student working under the supervision of Prof.Ashoke Sen. My main interest is in black holes in string theory. More specifically, I have worked on supersymmetric black holes in $N = 4$ superstring theory in four dimensions and Quantum Entropy Function formalism proposed by Ashoke Sen. I have also looked at some issues related to the non-holomorphic corrections to the prepotential in $N = 2$ theories.

Publications:

1. Nabamita Banerjee, Shamik Banerjee, Rajesh Kumar Gupta, Ipsita Mandal, Ashoke Sen *Supersymmetry, Localization and Quantum Entropy Function* JHEP 1002:091 (2010)

Preprints:

1. Shamik Banerjee, Rajesh Kumar Gupta, *Duality covariant variables for STU-model in presence of non-holomorphic corrections* arXiv:0905.2700 [hep-th]

Conference Attended:

1. *Strings 2009*, Italy, June 22-June 26 2009,

Atri Bhattacharya

During the academic year "2008-2009" I joined Prof. Raj Gandhi for my Ph.D. programme. Along with Sandhya Choubey and Atsushi Watanabe, we started working on a project related to ultra-high energy neutrinos, a preprint of which we put up on the arXiv server in November 2009 and is enumerated appropriately below. The work involves using spectral distortions of diffuse ultra-high energy neutrino flavour fluxes from distant cosmic sources such as active galactic nuclei to detect exotic physical phenomena like neutrino decay and Lorentz symmetry violation. We are currently working on an extension of this project to other physical phenomena.

I also started a project related to determination of the neutrino mass hierarchy from neutrino oscillation along with Manoj Kumar Mandal and my supervisor. This project is at its infancy as yet.

Preprints:

1. Atri Bhattacharya, Sandhya Choubey, Raj Gandhi and Atsushi Watanabe, *Diffuse Ultra-High Energy Neutrino Fluxes and Physics Beyond the Standard Model,* arXiv:0910.4396

Conference/Workshops Attended:

1. *Nu Horizons III*, India, February 2010.

Invited Lectures/Seminars:

1. *Diffuse ultra-high-energy neutrinos: A pointer to non-standard physics*, Nu Horizons III, Harish-Chandra Research Institute, Allahabad, February 2010.

Subhaditya Bhattacharya

I have been working on the collider signatures of different supersymmetric (SUSY) scenarios within the framework of gravity -mediated SUSY breaking (SUGRA) schemes, particularly in the context of the on-going Large Hadron Collider (LHC). In continuation to our earlier studies, we calculated non-universal gaugino mass ratios in context of different non-singlet representations in an underlying $SO(10)$ Grand-Unified Theory, and studied the low energy consistency of such high-scale breaking patterns. Also studied collider signature in multileptonic channels at some selected benchmark points allowed by the cold dark matter constraints provided by the WMAP data. We have recently shown that a non-universal scalar mass scenario with very heavy first two generation squarks and lighter third generation scalars, apart from keeping the FCNC and CP violation on board, leads to a large funnel region of cold dark matter relic-density constraint and can be discovered within the early run of the LHC. Also this model shows strikingly distinguishable features in terms of the collider signature from a mSUGRA scenario with similar gluino masses.

We also gave the first demonstration of unitarity violation in the sequential neutrino mixing matrix in a scenario with extra compact space-like dimensions. Gauge singlet neutrinos are assumed to propagate in one extra dimension, giving rise to an infinite tower of states in the effective four-dimensional theory. It is shown that this leads to small lepton-number violating entries in the neutrino mass matrix, which can violate unitarity on the order of one per cent.

Work in progress showing the effect of the intermediate scale for the non-universal gaugino masses which arise due to the presence of a dimension five operator in a supersymmetric theory with $SO(10)$ GUTs, and trying to address whether the case with an intermediate scale is distinguishable at the LHC from the one where this is set at the GUT scale itself.

Work in progress to find one of the most favourable supersymmetric spectra within the SUGRA framework and collider signals, that is likely to be discovered at the early run of the LHC.

Work in progress to distinguish models with high-scale non-universal Higgs mass scenarios from the minimal supergravity (mSUGRA) in context of the LHC.

Publications:

1. Subhaditya Bhattacharya, Utpal Chattopadhyay, Debajyoti Choudhury, Debottam Das, Biswarup Mukhopadhyaya, *Non-universal scalar mass scenario with Higgs funnel region of SUSY dark matter: a signal-based analysis for the Large Hadron Collider,* Phys.Rev. **D81**, 075009, (2010)
2. Subhaditya Bhattacharya, Paramita Dey, Biswarup Mukhopadhyaya, *Unitarity violation in sequential neutrino mixing in a model of extra dimensions,*

Phys.Rev. **D80**, 075013, (2010)

3. Subhaditya Bhattacharya, Joydeep Chakrabortty, *Gaugino mass non-universality in an SO(10) supersymmetric Grand Unified Theory: Low-energy spectra and collider signals,* Phys.Rev. **D81**, 015007, (2010)

Preprints:

1. Subhaditya Bhattacharya, Joydeep Chakraborty and Nishita Desai, *Impact of the intermediate scale in gaugino mass running in supersymmetric SO(10) Grand Unified Theory,* (in preperation)
2. Subhaditya Bhattacharya and Satya Nandi, *Supersymmetry signal at the LHC under the most favourable SUGRA scenario,* (in preparation)

Conference/Workshops Attended:

1. *Data to Theory at the LHC*, Shimla, India, December 2009,
2. *KEK-PH Meeting*, KEK, Tsukuba, Japan, February 2010

Visits to other Institutes:

1. Oklahoma State University, Tulsa, USA, August 2009,
2. University of Maryland, College Park, USA, September 2009,
3. SLAC, Palo Alto, USA, September 2009,
4. BNL, Brookehaven, USA, September 2009,
5. Northeastern University, Boston, USA, September 2009,
6. Pittsburgh University, Pittsburgh, USA, September 2009,
7. University of Wisconsin, Madison, USA, October 2009,
8. Northwestern University, Evanston, USA, October 2009,
9. University of Minnesota, Minneapolis, USA, October 2009,
10. University of Oklahoma, Norman, USA, October 2009,
11. University of California, Riverside, USA, October 2009,
12. Southampton University, Southampton, UK, November 2009,
13. Manchester University, Manchester, UK, November 2009,
14. Oxford University, Oxford, UK, November, 2009,
15. IPPP, Durham University, Durham, UK, November 2009,
16. University of Glasgow, Glasgow, UK, November 2009,
17. KEK, Tsukuba, Japan, February-March 2010.

Invited Lectures/Seminars:

1. *Relating High-Scale Non-universalities in SUGRA to the Low-scale Observables at the LHC*, Universities in USA and UK as listed above, August-November, 2009.

2. *Relating High-Scale Non-universalities in SUGRA to the Low-scale Observables at the LHC*, KEK, Japan, March 2010.

Academic recognition/Awards:

- Awarded post-doctoral fellowship from University of California, Riverside, USA.
- Awarded post-doctoral fellowship from DESY, Humburgh, Germany.

Sanjoy Biswas

I am working on collider aspects of supersymmetric theories in the context of the CERN Large Hadron Collider. In particular, I have worked on the mass reconstruction of supersymmetric particles in the long-lived stau scenario.

Currently, I am working on aspects of theories with non-universal Higgs mass analysed with the help of tau-polarisation.

Publications:

1. Sanjoy Biswas and Biswarup Mukhopadhyaya, *Chargino reconstruction in supersymmetry with long-lived staus*, Phys. Rev. D **81**, 015003, (2010).

Preprints:

1. Sanjoy Biswas, *Reconstruction of the left-chiral tau-sneutrino in supersymmetry with a right-sneutrino as the lightest supersymmetric particle*, arXiv:1002.4395 [hep-ph]

Conference/Workshops Attended:

1. *The 4th CERN-Fermilab Hadron Collider Physics Summer School*, CERN, Geneva, Switzerland, June 8-17, 2009.
2. *Workshop on LHC Physics*, Tata Institute of Fundamental Research, Mumbai, India, Oct 21-27, 2009.

Visits to other Institutes:

1. Indian Association for the Cultivation of Science, Kolkata, India, March-April, 2010.

Other Activities:

1. I have been the tutor of the Classical Electrodynamics course for the semester August- December, 2009.

Joydeep Chakrabortty

I am working on Grand Unified Theory (GUT) and Neutrino Physics. In context of GUT, we have propsed a simple mechanism to calculate the vacuum expectation values for any dimensional Higgs and it is applicable for any group. We have also shown the impact of dimension-5 operators in gauge coupling unification for non-supersymmetric and supersymmetric case. We have calculated the ratios of non-universal Gaugino masses at the high scale and did the low scale phenomenology. We have shown the effect of non-renormalizable operators in presence of the intermediate scales and their impact on gauge coupling unification.

I have worked on the neutrino mass models. We have proposed neutrino mas models in the context of left-right symetric theories and discussed their phenomenlogy.

In the context of neutrino physics few works are going on. Now I am working on Inverse seesaw mechanism, Leptogenesis.

Publications:

1. Gaugino mass non-universality in an SO(10) supersymmetric Grand Unified Theory: low-energy spectra and collider signals.
   Subhaditya Bhattacharya and Joydeep Chakrabortty.
   Phys. Rev. D **81** (2010) 015007.
2. GUTs with dim-5 interactions: Gauge Unification and Intermediate Scales.
   Joydeep Chakrabortty and Amitava Raychaudhuri.
   Phys. Rev. D **81** (2010) 055004.

Preprints:

1. Maximal mixing as a 'sum' of small mixings.
   Joydeep Chakrabortty, Anjan S. Joshipura, Poonam Mehta, Sudhir K. Vempati.
   e-Print: arXiv:0909.3116 [hep-ph].
2. TeV scale double seesaw in left-right symmetric theories.
   Joydeep Chakrabortty.
   e-Print: arXiv:1003.3154 [hep-ph].
3. Type I variant and a new seesaw in left-right symmetric theories.
   Joydeep Chakrabortty.
   Submitted in Journal.

Conference/Workshops Attended:

1. *'Summer School on Particle Physics in the LHC ERA'* Abdus Salam International Centre for Theoretical Physics (ICTP); Trieste, ITALY;
   15 June 2009 - 26 June 2009.

2. Joint ICTP-INFN-SISSA Conference: *Topical Issues in LHC Physics* the Abdus Salam International Centre for Theoretical Physics (ICTP) Strada Costiera 11, I-34014 Trieste, ITALY,
29 June - 2 July 2009.

Other Activities:

1. I have been the tutor of the Quantum Mechanics-I course for the semester August-December, 2009.

Nishita D. Desai

My research involves looking at possible signals of theories of particle physics beyond the Standard Model at the Large Hadron Collider (LHC). The Minimal Supersymmetric Standard Model (MSSM) is one such theory which postulates an extra symmetry of nature and predicts many new particles. This year, I have focussed on a particular case of the MSSM where baryon number violating couplings may be present. At the LHC, the presence of such couplings can cause resonant production of supersymmetric partners of quarks (called squarks).

I have looked at the case where a single coupling of the type λ''_{312} is present and causes resonant production of the stop (the partner of the top quark). We consider various possible decays of the stop and also address the question whether resonant stop production can be probed regardless of underlying high-scale parameters. We find that for heavy stops, the same-sign dilepton channel provides a very good reach upto stop masses of 1.5 TeV.

Publications:

1. Nishita Desai, Biswarup Mukhopadhyaya, *Signals of supersymmetry with inaccessible first two families at the Large Hadron Collider,* JournalPhys.Rev.D **80**, 055019, (2009)

Preprints:

1. Nishita Desai, Biswarup Mukhopadhyaya, *R-parity violating resonant stop production at the Large Hadron Collider,* arXiv:0102.2339

Conference/Workshops Attended:

1. *CERN-Fermilab Hadron Collider Physics Summer School 2009* , Switzerland, June 2009.
2. *Summer School on Particle Physics*, Italy, July 2009.
3. *Joint ICTP-INFN-SISSA Conference: Topical Issues in LHC Physics*, Italy, July 2009.
4. *Data to theory approach at the LHC*, Shimla, December 2009.

Visits to other Institutes:

1. Indian Association for Cultivation of Science, Kolkata, India, January-March 2010.

Rajesh Kumar Gupta

The quantum entropy function is a proposal which relates the entropy associated with the single centered extremal black hole to the path integral over string fields on $AdS_2 \times K$ (K is some compact space) near horizon geometry. In my first project (arXiv:0905.2686) I worked on the localization of path integral over string fields living on the near horizon geometry of supersymmetric extremal black hole. In four spacetime dimension, in the supersymmetric case, the isometry group of the near horizon geometry $AdS_2 \times S^2$ enhanced to supergroup $SU(1,1|2)$. Using this supergroup and localization techniques we showed that the path integral receives contribution only from a special class of field configuration which are invariant under a particular subgroup of $SU(1,1|2)$. We also constructed few examples of such field configurations.

In my second project I have worked on non-holomorphic corrections in $N = 2$ supergravity. It has been suggested earlier that the non-holomorphic corrections are necessary in order to get duality invariant free energy and entropy function. However, the way one incorporates the non-holomorphic corrections, makes the moduli fields non-covariant under duality transfromation and also their dualtiy transformations involves graviphoton field strength. In this work (arXiv:0905.2700) we constructed duality covariant moduli fields for STU-model perturbatively in powers of graviphoton field strength and showed their existence upto second order.

Publications:

1. N.Banerjee, S.Banerjee, R.K.Gupta, I.Mandal and A.Sen, *Supersymmetry, Localization and Quantum Entropy Function,* JHEP **02**, 091, (2010)

Preprints:

1. Shamik Banerjee and Rajesh Kumar Gupta, *Duality covariant variables for STU-model in presence of non-holomorphic corrections,* arXiv:0905.2700 [hep-th]

Conference/Workshops Attended:

1. *National Strings Meeting*, India, February, 2010

Visits to other Institutes:

1. University of Liverpool, Liverpool, U.K., October 2009,
2. Imperial College, London, U.K., October 2009
3. University of Swansea, Swansea, U.K., October 2009

Dhiraj Kumar Hazra

During the last year, my research work was focused on investigating inflationary models which lead to specific features in the scalar power spectrum that result in a better fit (than the standard, power law, primordial spectrum) to the recent data of the anisotropies in the Cosmic Microwave Background (CMB). In this context, I have been analysing as to how the introduction of a step in certain inflationary models perform against the various CMB datasets. I have also been studying the generation of features in two field inflationary models.

Other Activities:

1. I was the tutor for the course on '*General Theory of Relativity*' taught by Dr. L. Sriramkumar at the HRI graduate school during the semester of August–December, 2009.

Girish Pramod Kulkarni

My research interest centres in astrophysical cosmology. During the last academic year, I have studied cosmic reionization. We have derived an improved result for the formation rate of dark matter haloes. We have studied reionization in biased regions and suggested a promising observational probe. We have developed a semi-numerical model to study galaxy formation and evolution.

Publications:

1. J. S. Bagla, Girish Kulkarni, T. Padmanabhan, *Metal enrichment and reionization constraints on early star formation,* Monthly Notices of the Royal Astronomical Society, **397**, 2, (2009)

Preprints:

1. J. S. Bagla, Nishikanta Khandai, Girish Kulkarni, *Mass function of haloes: scale invariant models,* arXiv:0908.2702

Conference/Workshops Attended:

1. *Indian Conference on Cosmology and Galaxy Formation*, Kanpur, November 2009.
2. *Cosmological Reionization*, Allahabad, February 2010.

Academic recognition/Awards:

- Fulbright-Nehru Doctoral and Professional Research Fellowship, 2010–11.

Shailesh Lal

In this year, I have continued my work with Suvrat Raju in trying to understand simplifications in the structure of the one-loop s-matrix in gauge theories, both supersymmetric and non-supersymmetric. It is known that the s-matrix of $\mathcal{N} = 4$ super-Yang-Mills has no triangles or bubbles at one loop. Also, we know that any supersymmetric gauge theory has no rational remainders (rational terms) in its one-loop s-matrix. We considered the gluon s-matrix at one-loop in an arbitrary gauge theory and explicitly constructed theories with less supersymmetry, but no triangles or bubbles, and non-supersymmetric theories with no bubbles. None of these theories contained rational terms, which we showed in a follow-up work, where we also constructed non-supersymmetric theories with no rational terms, but having triangles and bubbles. To do so, we first showed that the contribution of fermions and scalars to gluon scattering at one-loop has certain interesting representation-theoretic structures. The contributions of matter to bubble and triangle coefficients depend on a few Dynkin indices of the representation in which matter is coupled to gluons. There is also a simplification in the case of supersymmetric theories, the contributions depend on still fewer indices. Similar structures show up when considering the contribution of matter to rational remainders. We used these structures to construct theories in a "decreasing order of simplicity", i.e., theories with no triangles, bubbles or rational terms, theories with no bubbles or rational terms, and finally, theories with no rational terms. This completes the classification of the "next-to-simplest" quantum field theories. In future work, we intend to examine whether these theories see similar structural simplification in amplitudes with external matter as well.

Publications:

1. Shailesh Lal and Suvrat Raju, *Next-to-Simplest Quantum Field Theories* Physical Review D, (accepted in).

Preprints:

1. Shailesh Lal and Suvrat Raju, *Rational Terms in Theories with Matter,* arXiv:1003.5264 .

Conference/Workshops Attended:

1. *The 4^{th} Asian Winter School on Strings, Particles, and Cosmology*, India, 11-20 January 2009,
2. *The National Strings Meet*, India, 10-15 February 2009,
3. *The Spring School on Superstring Theory and Related Topics*, Italy, 22-30 March 2009.

Lectures/Seminars:

1. *The Next-to-Simplest Quantum Field Theories*, The National Strings Meet, IIT Powai, Mumbai, February 2010.
2. *The Next-to-Simplest Quantum Field Theories*, The Spring School in Superstring Theory and Related Topics, ICTP, Trieste, Italy, March 2010.

Other Activities:

1. Tutored the QFT-II course, alongwith Nishita Desai, in the 2009 Academic Session.

Ipsita Mandal

We have been studying various aspects of Galilean Conformal Algebra, which is obtained as the nonrelativistic limit of the relativistic Conformal Algebra. In particular, we looked at the special case of two dimensions. We also studied the supersymmetric extension of the algebra in 2d.

Preprints:

1. Arjun Bagchi, Rajesh Gopakumar, Ipsita Mandal, Akitsugu Miwa, *GCA in 2d* , arXiv:0912.1090
2. Ipsita Mandal, *Supersymmetric Extension of GCA in 2d* , arXiv:1003.0209

Visits to other Institutes:

1. LPTHE, Paris, France, November 2009 - June 2010.

Ayan Mukhopadhyay

I have continued my work on understanding universal nonequilibrum phenomena in strongly coupled conformal gauge theories with gravity duals. Along with Ramakrishnan Iyer, I have proposed general phenomenological equations which give the time evolution of the energy-momentum tensor and can be claimed to capture all basic nonequilibrium processes like decoherence, relaxation and hydrodynamics at sufficiently late time. These equations include the equations for conservation of energy-momentum tensor, but also independent equations of motion for the nonequilibrium shear stress tensor. We have argued that in any quantum field theory there exists *conservative* states which can be characterized by the energy-momentum tensor alone and whose dynamics can be determined completely by our phenomenological equations of motion for energy-momentum tensor. We have established the existence of these states in the weak coupling perturbative limit and have then argued for their existence at strong coupling using gauge/gravity duality. The universal sector of the gauge theories with gravity duals can be argued to be constituted by conservative states at strong coupling. A class of these states are purely hydrodynamic in nature and their gravity duals are known. Our conjecture amounts to a prediction of all solutions of five dimensional pure gravity in presence of a negative cosmological constant with smooth future horizons, as these define the universal sector in gauge/gravity duality. We make preliminary investigations into the origin of the entropy current, hence irreversibility, and also argue how we can use our equations to model nonequilibrium phenomena in realistic theories like QCD.

In another work, I have analyzed hydrodynamics in a novel nonrelativistic limit of gauge/gravity duality. In this limit we have Galilean Conformal Algebra (GCA) as the spacetime symmetry which includes the nonrelativistic limit of all the generators of the relativistic conformal group in same spacetime dimensions along with an infinite dimensional extension of this finite subgroup. I have analyzed how GCA can be symmetry of hydrodynamics and how it restricts equation of state, and the viscosity, for instance, as a function of temperature and pressure. This analysis gives us valuable insights on how the nonrelativistic limit should be taken dynamically so that the theory obtained in this limit contains hydrodynamics.

Publications:

1. R. Iyer and A. Mukhopadhyay, *"An AdS/CFT Connection between Boltzmann and Einstein,"* Phys. Rev. D **81**, 086005 (2010) [arXiv:0907.1156 [hep-th]].
2. A. Mukhopadhyay, *"A Covariant Form of the Navier-Stokes Equation for the Galilean Conformal Algebra,"* JHEP **1001**, 100, (2010) [arXiv:0908.0797 [hep-th]].

Conference/Workshops Attended:

1. *Fifth Aegean Summer School, From Gravity to Thermal Gauge Theories*, Greece, September 2009.
2. *Fourth Asian Winter School in Strings, Particles and Cosmology*, India, January 2010.

Visits to other Institutes:

1. IMSc, Chennai, India, June 2009,
2. CHEP, IISc, Bangalore, India, July 2009,
3. LPTHE, Paris, France, September-October 2009,
4. ICTP, Trieste, Italy, October 2009,
5. University of Amsterdam, Amsterdam, Netherlands, October 2009,
6. ULB, Brussels, Belgium, October 2009,
7. Imperial College, London, UK, October 2009,
8. Oxford University, Oxford, UK, October 2009,
9. DAMTP, University of Cambridge, Cambridge, UK, October 2009,
10. Harvard University, Cambridge, Massachusetts, USA, December 2009,
11. California Institute of Technology, Pasadena, California, USA, December 2009,
12. TIFR, Mumbai, India, January 2010.

Invited Lectures/Seminars:

1. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, CHEP, Indian Institute of Science, Bangalore, India, July 2009
2. *"Kinetic Theory and Pure Gravity in AdS,"* Fifth Aegean Summer School, Adamas, Milos Island, Greece, September 2009
3. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, LPTHE, Paris, France, September 2009
4. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, ICTP, Trieste, Italy, October 2009
5. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, Institute for Theoretical Physics, University of Amsterdam, Amsterdam, Netherlands, October 2009
6. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, ULB, Brussels,Belgium, October 2009
7. *"Kinetic Theory and Pure Gravity in AdS"*, Imperial College, London, UK, October 2009
8. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*,DAMTP, University of Cambridge, UK, October 2009
9. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, String Duality Seminar, Harvard University, USA, December 2009

10. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, California Institute of Technology, USA, December 2009
11. *"Universal Phenomena in Strongly Coupled Gauge Theories and Gravity"*, TIFR, India, January 2010

Satyanarayan Mukhopadhyay

I have been studying the collider signatures of various possible extensions of elementary particle physics beyond the Standard Model. In particular, I have worked on the T-parity violating effects of the Wess-Zumino-Witten anomaly term in the Littlest Higgs model. We have made a detailed study of the scenario where the lightest T-odd particle in this model can be reconstructed from invariant mass peaks in the opposite sign same flavour dilepton or the four lepton channel at the Large Hadron Collider.

In some other ongoing projects, I am working on the LHC inverse problem and the signatures of Supersymmetry with lepton number violation.

Publications:

1. Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, Andreas Nyffeler, *Dilepton and Four-Lepton Signals at the LHC in the Littlest Higgs Model with T-parity Violation,* JHEP**05(2010)001**, (2010).

Conference/Workshops Attended:

1. *Data to theory approach at the LHC*, IIAS, Simla, India, December, 2009.
2. *LHC Physics Workshop*, TIFR, Mumbai, India, October, 2009.

Viveka Nand Singh

1. We are investigating the effect of "antisite disorder"(ASD) in double perovskite having the form $A_2BB'O_6$. First we generated the ASD configuration from an effective lattice-gas model developed by Sanyal et al. EPJB (2008), then used a real space, exact diagonalization based Monte Carlo technique called "Travelling Cluster Approximation" developed by S.Kumar et al., EPJB (2006), that allows one to handle fermions in the background of strong spatial fluctuations. Our microscopic model has the usual couplings of the ordered double perovskite, and an additional antiferromagnetic coupling when two magnetic(B) ions are nearest neighbour. We found that ASD in double perovskite ferromagnets causes following changes in properties: (1) There is suppression in the saturation moment with ASD. (2) There is loss of half metallicity with ASD. (3) It shows metal insulator transition at large ASD. (4) There is enhancement in the low temperature magnetoresistance with ASD.
2. We are investigating the non-ferromagnetic phases and phase coexistence in antisite disordered double perovskite. Here we have measured antiferromagnetic reflections and transport in the presence of antisite disorder. We are exploring the phase coexistence regime to fully characterise it.
3. We wrote an effective magnetic model for ferromagnetic phases and benchmarked it with respect to full electronic calculation. Using this model we want to study spin-wave excitations (setuped by Subrat K Das) in antisite disordered double perovskite.
4. We have setuped disordered configurations in three dimension using effective lattice-gas model. We have calculated magnetization and transport on these configurations. Here we want to investigate how much physics can be captured by disorder effect only, then we will incorporate e-e interaction effect on it.

Preprints:

1. Viveka Nand Singh and Pinaki Majumdar, *Antisite Domains in Double Perovskite Ferromagnets: Impact on Magnetotransport and Half-metallicity.*

Conference/Workshops Attended:

1. *Advanced theories for functional oxides*, HRI, Allahabad, India, 11-13 January, 2010.

Rajarshi Tiwari

Previous year I started my work on the phenomenology of double perovskites (DP) ($A_2BB'O_6$, A= Alkali,rare earth, $B, B' =$ transition metals, $O =$ oxygen) based on models which consist of a lattice with e^- coupled to classical spins (representing the localized e^- well below Fermi level in the B, B' atoms). We studied the 2D model for ordered DPs with 2 magnetic sites, explored the GS magnetism and predicted the possibility of ferromagnetic band insulators with large T_c.

In the current year I continued working on DPs with more realistic model for DPs with single magnetic site in 3-D (e.g. Sr_2FeMoO_6, an FM half metal). In 3-D the system faces a serious *geometrically induced magnetic frustration* as the magnetic site of the material lies on an effective FCC lattice. As a result, GS magnetic phase diagram of the model shows not only ferro and collinear anti-ferro phases, but also *non-collinear magnetic phases*. Our studies of this model called *Double Exchange on a Geometrically Frustrated Lattice*, predicts the presence of the non-collinear magnetic ordering in DPs with 1 magnetic site, and explains their reduced T_c. In summary, we provide the first richest GS magnetic phase diagram showing the stability of various collinear/non-collinear magnetic phases, and e^--density versus T_c phase diagram showing the thermal stability of these phases for a class of DPs with 1 magnetic site. We also find that the interplay of the second magnetic site, quickly destroys the magnetic frustration. In general, the anti-ferromagnetism in the stage of geometric frustration is not yet understood well for itinerant e^- magnetism. This also opens some interesting and relevant problem in current research trends for our interest. While working on the above mentioned problems, I set up a numerical scheme using *real space Monte-Carlo based on TCA*, to explore the finite temperature properties, and *an extended variational scheme* to explore the non-collinear magnetic phases in the system.

Preprints:

1. Rajarshi Tiwari and Pinaki Majumdar, *Non-collinear Magnetic Order in the Double Perovskites: Double Exchange on a Geometrically Frustrated Lattice*. (in preparation)

Conference/Workshops Attended:

1. *Workshop on combining ab initio methods with many body theory (ATHENA EU-India project)*, Harish-Chandra Research Institute, Allahabad, INDIA, January 11-13, 2010.

Subrat Kumar Das

I have joined the institute on 16th of March year 2009. In collaboration with Prof. Pinaki Majumdar and Mr. Viveka Nand Singh I am working in the are of ”strongly correlated elctron systems”, particularly we are interested in ”spin-wave excitations in inhomogeneous magnets” such as manganites and double perovskites. This study require (i) a spin-wave theory (at least at noninteracting level), (ii) (inhomogeneous) ground state spin configurations and (iii) (at least nearest-neighbour) spin-spin exchange couplings. In collaboration with Prof. Majumdar I developed the first part and the second and third parts are done by Mr. Singh. We have used the simplest looking spin Hamiltonian the effective Heisenberg model for our study. Due to the inhomogenity nature of the system there were many nontrivial difficulties in analitical calculations which consumed most part of the time and are now settled. In parallel we developed the numerical part and reproduce the results for standard spin orderings like ferromagnet and antiferromagnet. Our aim is to calculate excitations for manganites and do a comparison with the existing experimental results and to make some predictions in case of double perovskites where no experiments have not yet been done. Very recently we obtained some interesting results for some simple orderings in one dimension. The results show some features as seen in the neutron scattering experiments in manganites. Currently we are setting up an analytical description of these results and also preparing a preliminary version of the manuscript with these results. In parallel we are calculating for the two dimension spin configurations for the double perovskites. Next we will (i) go to three dimensional configurations where comparison with the experimental results would be quite meaningful and (ii) calculate for manganites.

Sanjoy Datta

Rare earth manganites constitutes an interesting class of strongly correlated system and shows fascinating phenomena such as colossal magnetoresistance, charge ordering etc. Recently it was noticed experimentally that their parent (undoped) compounds exhibit a variety of puzzling features especially in relation to the transition temperature associated with the orbital ordering. We believe that the microscopic origin of this feature arise from cooperative Jahn-Teller distortions and cooperative tilting of the oxygen octahedra surrounding the manganese ions. Both of these are strongly affected by small variations such as change in ionic radius. Based on this picture, we have constructed a microscopic model involving classical strain variables; thermodynamics can be studied using Monte-Carlo methods. I have been able to obtain the experimentally observed orbital ordering pattern from these studies. I plan to study the consequences of ionic radii changes as well as effect of doping on the thermodynamic properties of the model Hamiltonian.

Other Activities:

1. I was a teaching assistant for the statistical mechanics course offered during January-May, 2010.
2. Condensed Matter talk on *Discovery of magnetic monopole in spin-ice system*.

Bobby Ezhuthachan

One of the two main projects I was involved in during this period was to write down a higher derivative version of the ABJM action- A Chern Simons matter theory in three dimensions, which has been conjectured to be the theory describing the IR fixed point of N= 8 Super Yang-Mills theory-the theory describing N D2 branes in flat space, in lowest order in α'. The higher derivative correction, had been worked out previously by me along with my collaborators, in a special limit, where the ABJM theory has a gauge group $SU(2) \times SU(2)$ and enhanced symmetries.

In the ongoing work, we used two checks to fix the higher derivative version of the ABJM theory. The first being that it reduces to the known correction, that we had worked out previously in the special limit mentioned above. The second check being that it correctly reproduces the known correction to the D2 brane action.

We have made partial progress in this project as of now. We have managed to fix the coefficients of the four derivative as well as the three derivative terms using just the first check. To fix the other terms, it seems that we have to still use the second check. This is still work in progress.

The other main project has been to check whether the higher derivative BLG action that we had constructed previously was indeed invariant under N=8 susy, something we had not checked previously. This is sill work in progress.

Conference/Workshops Attended:

1. *SRINGS 09*, ITALY, JUNE, 2009
2. *FIFTH REGIONAL MEETING IN STRING THEORY*, GREECE, JULY, 2009.
3. *NSM '10*, INDIA, FEB, 2010

Visits to other Institutes:

1. IISER TVM, TRIVANDRUM, INDIA, JAN 2010,
2. IITB, POWAI, INDIA, FEB 2010.
3. TIFR, MUMBAI, INDIA, JAN 2010

Invited Lectures/Seminars:

1. *STRINGS AT STRONG COUPLING*, IISER TVM, TRIVANDRUM, JAN 2010.
2. *STRINGS AT STRONG COUPLING*, IITB, MUMBAI, FEB 2010.

Kirtiman Ghosh

I have joined Harish-Chandra Research Institute on 25th Nov. 2009. During December 2009 to March 2010, I am working on the phenomenology of Universal Extra Dimension (UED) model. In particular, I am investigating multilepton signatures of Universal Extra Dimension Model at the LHC. In this project, I am investigating same sign di-lepton (SSD), opposite sign di-lepton (OSD), tri-lepton and 4-lepton signature, resulting from the pair production of 1st Kaluza-Klein (KK) excitation of Universal Extra Dimension model. I am also computing the Standard Model contribution to the above mentioned signals. In an another project, I am working on the LHC inverse problem. In particular, I am trying to discriminate KK-parity conserving UED, R-parity violating SUSY, KK-parity violating UED and T-parity violating littlest Higgs model in 4-lepton channel.

Preprints:

1. B. Bhattacherjee and K. Ghosh, *Probing minimal Universal Extra Dimension model in leptonic channel at the LHC,* (in preparation)
2. K. Ghosh, B. Mukhopadhyaya and S. Mukhopadhyay, *Model discrimination at the LHC,* (in preparation).

Conference/Workshops Attended:

1. *LHC and New Frontiers of Particle Physics*, University of Calcutta, Kolkata, India, December 2009,
2. *Data to theory at the LHC*, Shimla, India, December 2009,
3. *Workshop on High Energy Physics Phenomenology 2010*, Ahmedabad, January 2010.

Harvinder Kaur Jassal

The assumption that the distribution of dark energy is homogeneous at all length scales is inconsistent with the observational fact that dark matter is distributed inhomogeneously. Therefore dark energy, if not a cosmological constant, has to cluster. We find that on length scales comparable to or greater than the Hubble radius, the perturbation in dark energy can become comparable to perturbations in matter. We have further demonstrated that quintessence dark energy results in suppression of matter power spectrum relative to the cosmological constant model.

Dark energy perturbations in fluid models suppress matter perturbations as compared to the corresponding smooth dark energy model. Matter perturbations are suppressed as compared to the cosmological constant model. For scales smaller than the Hubble radius, for a positive sound speed, the evolution of matter perturbations is indistinguishable from a smooth dark energy model. Matter perturbations are suppressed as compared to the ΛCDM model. As long as the sound speed is positive the evolution of matter perturbations is indistinguishable from a smooth dark energy model. This is true for scales smaller then the Hubble radius. Dark energy perturbations in a fluid model emulate that of a scalar field model very well below the Hubble scale but start to differ at larger scales. Therefore the fluid model is not a good approximation at these scales. This also implies that the growth of perturbations at large scales depends on the details of the model even though the background evolution is the same. A separate analysis is therefore required for every model.

I have studied evolution of dark energy perturbations in canonical scalar field models distinctly classified as thawing and freezing models. The dark energy equation of state evolves differently in these classes. In freezing models, the equation of state deviates from that of a cosmological constant at early times. For thawing models, the dark energy equation of state remains near that of the cosmological constant at early times and begins to deviate from it only at late times. Since the dark energy equation of state evolves differently in these classes, the dark energy perturbations too evolve differently. In freezing models, since the equation of state deviates from that of a cosmological constant at early times, there is a significant difference in evolution of matter perturbations from those in the cosmological constant model. In comparison, matter perturbations in thawing models differ from the cosmological constant only at late times. This difference provides an additional handle to distinguish between these classes of models and this difference should manifest itself in the ISW effect.

Publications:

1. H. K. Jassal, J. S. Bagla, T. Padmanabhan, *Understanding the origin of CMB constraints on Dark Energy*, to appear in MNRAS.

2. H. K. Jassal, *A comparison of perturbations in fluid and scalar field models of dark energy*, Phys. Rev. D79, 127301 (2009)
3. H. K. Jassal, *Evolution of perturbations in distinct classes of canonical scalar field models of dark energy*, Phts. Rev. D81, 083513 (2010)

Conference/Workshops Attended:

1. Gravitation & Astronomy: Frontiers in Theory & Observations (First IUCAA reunion meeting), IUCAA, Pune, India (August 2009).
2. Cosmological Reionization, HRI, Allahabad, India (February 2010).

Visits to other Institutes:

1. Indian Institute of Science Education and Research (I.I.S.E.R.), Mohali, India, October-November, 2009.
2. Indian Institute of Science Education and Research (I.I.S.E.R.), Pune, India, January, 2010.
3. Centre for excellence in Basic Sciences, Mumbai University Kalina Campus, Mumbai, India, January, 2010.
4. Physics Department, Panjab University, Chandigarh, India, March, 2010.

Invited Lectures/Seminars:

1. *Perturbations in dark energy*, Gravitation & Astronomy: Frontiers in Theory & Observations (First IUCAA reunion meeting), IUCAA, Pune, India (August 2009).

Sushan Konar

Many of the characteristic properties of the millisecond pulsars found in globular clusters are markedly different from those in the Galactic disc. We find that one such physical parameter is the surface magnetic field strength. Even though the average spin-periods do not differ much the average surface magnetic field is 2-5 times larger in the globular cluster pulsars. This effect could be apparent, arising due to one or more of several biases. Alternatively, we find that this effect could be real, a result of preferential recycling of pulsars in tight binaries where the mass transfer takes place at high accretion rates.

Collaborators - Manjari Bagchi, West Virginia University, West Virginia Bhaswati Bhattacharya IUCAA, Pune

In general the formation route of the millisecond pulsars in the globular clusters are expected to be very different from those in the Galactic disc. This is due to the large rates of stellar collisions in the clusters. The channels through which a normal pulsar could be recycled to generate a millisecond pulsar could be many. Accordingly the nature of the orbital parameters also show a large variation compared to the disc objects. We investigate the different channels of millisecond pulsar formation in globular clusters and look at the effect of the multiple stellar interactions on the orbital parameters of the ensuing binary pulsars.

Collaborator - Dipankar Bhattacharya, IUCAA, Pune

In recent years a number of accreting X-ray millisecond pulsars and X-ray bursters have come to be observed. According to the theory of pulsar recycling these are immediate precursors of the radio millisecond pulsars and are expected to turn into those once the accretion stops. We look at the spin-periods and the magnetic fields of these accreting pulsars and compare with the expected values assuming a standard theory of field evolution (Konar & Bhattacharya 1997). It is seen that a number of these pulsars come from systems with ultra-low mass companions - very low mass white-dwarfs or brown dwarfs and consequently have rather unusual evolutionary history.

Publications:

1. Raka Dona Ray Mandal, Sushan Konar, Mira Dey, Jishnu Dey, *The micro-glitch in PSR B1821-24 : A case for a strange pulsar?*, Mon. Not. R. Astron. Soc. **399**, 822, (2009)

Preprints:

1. Sushan Konar, *The Magnetic Fields of Millisecond Pulsars in Globular Clusters* (submitted to Mon. Not. R. Astron. Soc.)

2. Sushan Konar, Dipankar Bhattacharya, *The Accreting Millisecond Pulsars* (in preparation)
3. Sushan Konar, Manjari Bagchi, *Generation of Millisecond Pulsars in Globular Clusters* (in preparation)
4. Sushan Konar, Bhaswati Bhattacharya, *Orbital evolution of binary and millisecond pulsars* (in preparation)

Conference/Workshops Attended:

1. *Relativistic Whirlwind*, SISAA-ASICTP, Trieste, Italy, June, 2010

Visits to other Institutes:

1. IUCAA, Pune, India, March 2010
2. SISAA, Trieste, Italy, May-June 2010

Shailesh Gajanan Kulkarni

We studied possible quantum gravitational effects, which may break Lorentz invariance, on the response of Unruh-Dewitt detector. In particular we considered a rotating, monopole detector that is coupled linearly to a massless scalar field which is governed by a certain dispersion relation in flat spacetime. since it does not seem to be possible to evaluate the response of the detector analytically, we resort to numerical computation. We also discuss the response of the rotating detector in the presence of a cylindrical boundary on which the scalar field is constrained to vanish. We find that the corrections to the standard results due to the modified dispersion relation prove to be rather small. This work is done in collaboration with Dr. Sashideep Gutti (HRI) and Dr. L. Sriramkumar (HRI).

The work is in progress on the anisotropic inflationary models. In particular we are studying the evolution of scalar perturbations on the anisotropic background (Bianchi-I spacetime). This work is in collaboration with Dr. L Sriramkumar (HRI)

The work has been done on the symmetries of Classical Liouville theory. The interplay between the diffeomorphism and conformal symmetries (a feature common in quantum field theories) is shown to be exhibited for the case of black holes in two dimensional classical Liouville theory. We show that although the theory is conformally invariant in the near horizon limit, there is a breaking of the diffeomorphism symmetry at the classical level. On the other hand, in the region away from the horizon, the conformal symmetry of the theory gets broken with the diffeomorphism symmetry remaining intact. This work is done in collaboration with Dr. Rabin Banerjee(SNBNCBS, kolkata) and Dr. Sunandan Gangopadhyay (Department of Physics and Astrophysics, West Bengal State University, Barasat).

Publications:

1. Rabin Banerjee, Sunandan Gangopadhyay and Shailesh Kulkarni, *Nonconservation of energy-momentum tensor in classical Liouville theory,* Europhys.Lett **89**, 11003, (2010)

Preprints:

1. Sashideep Gutti, Shailesh Kulkarni and L. Sriramkumar, *Modified dispersion relations and the response of the rotating Unruh-DeWitt detector* arXiv: 1005.1807 [gr-qc]

Conference/Workshops Attended:

1. *Field Theoretic Aspects of Gravity (FTAG-VIII)* , India, April 2010,

Visits to other Institutes:

1. Tata Institute for Fundamental Research, Mumbai, India, February 2010,

Invited Lectures/Seminars:

1. *Hawking radiation, anomalies and vacuum states*, TIFR, Mumbai, February 2010.

Meduri Chakravartula Kumar

The missing energy signals play a vital role in the search of physics beyond the standard model at the current LHC experiments. One such possible new physics scenario that offers an explanation to the hierarchy problem is the large extra dimensional (ADD) model. In this model, the compactification of the extra spatial dimensions leads to the tower of Kaluza-Klein (KK) modes. These KK modes when produced at the LHC experiments can escape the experimental detection and cause the missing energy signals. However, at the LHC it is important to compute the higher order QCD corrections to these predictions for they can enhance the production cross sections and minimize their scale uncertainties.

In this context we have studied the associated production of the massive vector boson and the KK modes of the graviton in the ADD model to NLO in QCD using semi-analytical two cut-off phase space slicing method. In the case of ZG_{KK} production we have obtained various kinematic distributions and the K-factors are found to be around 1.3 (1.1) for $\sqrt{S} = 14$ TeV (7 TeV). The work is in progress for the WG_{KK} cross sections.

Preprints:

1. M.C.Kumar, Prakash Mathews, V. Ravindran and Satyajit Seth, *Vector boson production in association with KK modes of the ADD model to NLO in QCD at LHC,* eprint arXiv:1004.5519 [hep-ph]

Conference/Workshops Attended:

1. *Data to Theory at the LHC*, Simla, India, December, 2009.
2. *Workshop on High Energy Physics Phenomenology (WHEPPXI)*, Ahmedabad, India, January, 2010.

Invited Lectures/Seminars:

1. *Di-photon production to NLO QCD in Extra dimension models at the LHC*, Workshop on High Energy Physics Phenomenology, Physical Research Laboratory, Ahmedabad, January, 2010.

Yoshinori Matsuo

It is important to understand the phase structure of QCD. An important feature is the critical end point where the first order transition from the Hadronic phase to QGP phase ends. The fluctuation of the conserved charge is one of signals of QGP formulation. The quark number susceptibility measures the response of QCD to a change of the chemical potential. A peak in the quark number susceptibility is confirmed by recent lattice calculations. This implies that there is an end point of the first order transition.

In this work, we evaluated the quark number susceptibility by using the AdS/CFT correspondence. We first considered the hard wall model in which a cut off is introduced. In this case, we obtained a peak with increasing the chemical pontential. However, each coefficient does not depend on temperature if we expand the quark number susceptibility with resepct to the chemical potential. This is different from the lattice result. We considered the soft wall model, in which we introduced an additional dilation factor to reproduce the potential wall in the gravity side. Then, we obtain the temperature dependence. We also calculated the quark number susceptibility under the existence of the external magnetic field.

Preprints:

1. Y. Kim, Y. Matsuo, W. Sim, S. Takeuchi and T. Tsukioka, *Quark Number Susceptibility with Finite Chemical Potential in Holographic QCD,* arXiv:1001.5343 [hep-th], to be published in JHEP.

Conference/Workshops Attended:

1. *National String Meeting*, India, February 2010.
2. *Recent Advances in Gauge Theories and CFTs*, Japan, March 2010.
3. *KEK Theory Workshop 2010*, Japan, March 2010.

Visits to other Institutes:

1. Kyoto University, Japan, March 2010,

Akhilesh Nautiyal

An important advance in theoretical cosmology is the idea of inflation- a period of rapid accelerated expansion during the early universe before Big-Bang nucleosynthesis. It was introduced to solve certain problems of the standard model of cosmology, and later it was realized that it not only solves the problems of the standard model of cosmology but also provides seeds for the anisotropy in cosmic microwave background (CMB) and structures in the universe. Inflation predicts a nearly scale invariant, adiabatic and nearly Gaussian primordial power spectrum of the density perturbations. These features were first confirmed by Cosmic Background Explorer (COBE). The precise measurements of CMB anisotropy, being done by Wilkinson Microwave Anisotropy Probe (WMAP) and other ground based, balloon based and satellite based experiments, are also consistent with the early period of inflation. During inflation, the potential energy of a scalar field called inflaton dominates the energy density of the universe. CMB observations put tight constraints on the parameters of the inflaton potential. Although the predictions of inflation are almost consistent with the CMB observations, we lack a unique model of inflation and also the values of the parameters of the inflaton potential required to satisfy observations are not natural from particle physics point of view. CMB observations also show some features on large scale anisotropy which are not well understood. For instance, the quadrupole is suppressed and there are also a few other glitches at low multipoles.

To explain these discrepancies and to understand the physics of the early universe there are large number of attempts to embed inflation in some high energy theory. There are some alternatives to inflation too. One of which is the idea of contracting phase preceding the ongoing expansion phase. In such cases the scale factor has a bounce at the transition point. These models also provide a causal mechanism to generate density perturbations on large scales. It is not possible to achieve such a bounce with pure Einstein's gravity and matter satisfying the usual energy conditions. But non-singular bounce in the scale factor may be achieved by string theory and higher derivative gravity. The bouncing solutions for the scale factor can also be achieved by considering a closed universe with a scalar field. We are studying these bouncing models. We are trying to understand cosmological perturbations in these models and trying to explore that whether these models can provide the required features in the low l anisotropy of CMB.

There are some models in which inflation can be achieved by the kinetic energy of the scalar field. The kinetic terms in the Lagrangian of the scalar field for these kind of models are not the standard terms and these are called non-canonical kinetic terms and can be derived by string theory. One example of such models is tachyon inflation. We are also studying inflation with these kind of models in the presence of non-minimal coupling of the scalar field with gravity. It was shown by Anjan Sen et al (Gen.Rel.Grav.42:821-838,2010) that it is possible to have an inflationary solution in early time as well as late time

accelerating phases in these models. Now we are trying to understand the evolution of primordial density perturbations in these models.

As mentioned earlier, there have been several attempts to construct the particle physics models of inflation. One of them is natural inflation in which inflaton is the pseudo Nambu Goldstone Boson (PNGB) of some broken symmetry. To have successful inflation with PNGB the spontaneous symmetry breaking scale has to be at Planck scale. We showed earlier that this scale can be reduced to the GUT scale if we consider this model in the warm inflationary scenario. In warm inflation radiation is also present during inflation but it is sub-dominant. The slow-roll motion of the inflaton is achieved by the dissipation of the scalar field into the radiation and Hubble damping. So one can have slow-roll inflation with natural values of the parameters of the inflaton potential. But due to the presence of thermal bath, inflaton potential gets large thermal corrections that can destroy slow roll inflation.Therefore, one requires supersymmetry to achieve warm inflation as the super partner of the inflaton can provide cancellation of such thermal corrections. We are, at present, trying to understand whether the shift symmetry of PNGB potential can provide suppression of large thermal corrections and at the same time large amount of dissipation to have warm inflation.

Conference/Workshops Attended:

1. *ICCGF 09 (Indian conference on cosmology and galaxy formation)*, Kanpur, India, October 30-November 1, 2009.
2. *WHEPP XI (Workshop on high energy physics phenomenology)*, Ahmedabad, India, January 2-13, 2010.
3. *Nu HoRizons III (Neutrinos in physics, astrophysics and cosmology)*, Allahabad, India, February 8-10, 2010.
4. *REION (A meeting on cosmological reionization)*, Allahabad, India, Feb 16-20, 2010.

Visits to other Institutes:

1. Jamia Millia Islamia, Delhi, India, May 5-14, 2010,

Invited Lectures/Seminars:

1. *Natural inflation at the GUT scale*, ICCGF 09, Indian institute of technology, Kanpur, Oct 30-Nov 1, 2010.

Andreas Nyffeler

My field of research is phenomenological particle physics. I work on precision tests of the Standard Model, mainly the muon $g-2$, 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, in signatures of New Physics models at colliders like the Large Hadron Collider (LHC), and in the non-perturbative, hadronic low-energy structure of the strong interactions (QCD).

I. Hadronic light-by-light scattering contribution to the anomalous magnetic moment of the muon

I continued to work on the long-term project of studying the hadronic light-by-light (had. LbyL) scattering contribution to the muon $g-2$. Whereas the evaluation of the hadronic vacuum polarization contribution to the muon $g-2$ is likely to be improved considerably in the next few years with new experimental data on the cross-section $e^+e^- \to$ hadrons at various colliders, the estimates of had. LbyL scattering are currently all based on hadronic models. This leads to large uncertainties in the Standard Model (SM) prediction for the muon $g-2$ and makes it difficult to interpret the presently observed deviation of about three standard deviations from the experimentally measured value. With several members from the KLOE Collaboration at the Daphne collider in Frascati, Italy, I am trying to assess, how well the upcoming KLOE-2 experiment could measure some of the form factors of photons with various hadrons and how this would affect the precision of the theoretical evaluation of the had. LbyL scattering contribution. This should allow to better control the hadronic uncertainties in the SM prediction of the muon $g-2$, which will in particular be important in view of a new planned muon $g-2$ experiment at Fermilab which aims at a factor of four-fold improvement in precision.

II. Dilepton and Four-Lepton Signals at the LHC in the Littlest Higgs Model with T-parity Violation

In the presence of the T-parity violating Wess-Zumino-Witten (WZW) anomaly term, the otherwise stable heavy photon A_H in the Littlest Higgs model with T-parity (LHT) decays to either Standard Model (SM) gauge boson pairs, or to SM fermions via loop diagrams. Together with Satya Mukhopadhyay and Biswarup Mukhopadhyaya, we made a detailed study of the collider signatures where the A_H can be reconstructed from invariant mass peaks in the opposite sign same flavor dilepton or the four-lepton channels. This enables one to obtain information about the fundamental symmetry breaking scale f in the LHT and thereby the low-lying mass spectrum of the theory. In addition, indication of the presence of the WZW term can give hints of the possible UV completion of the LHT via strong dynamics. The crucial observation of our study was that the sum of all production processes of heavy T-odd quark pairs has a sizeable cross-section at the LHC and these T-odd particles eventually all cascade decay down to the heavy photon A_H. We showed that for certain

regions of the parameter space with either a small f of around 500 GeV or relatively light T-odd quarks with a mass of around 400 GeV, one can reconstruct the A_H even at the early LHC run with $\sqrt{s} = 10$ TeV and a modest integrated luminosity of $200\ \mathrm{pb}^{-1}$. At $\sqrt{s} = 14$ TeV and with an integrated luminosity of $30\ \mathrm{fb}^{-1}$, it is possible to cover a large part of the typical parameter space of the LHT, with the scale f up to 1.5 TeV and with T-odd quark masses almost up to 1 TeV. In this region of the parameter space, the mass of the reconstructed A_H ranges from 66 GeV to 230 GeV.

Publications:

1. F. Jegerlehner and A. Nyffeler, *The Muon $g-2$,* Physics Reports **477**, 1, (2009)
2. A. Nyffeler, *Hadronic light-by-light scattering in the muon $g-2$: a new short-distance constraint on pion exchange,* Proceedings of Science (CD09) 080 (arXiv:0912.1441 [hep-ph])
3. S. Mukhopadhyay, B. Mukhopadhyaya, A. Nyffeler, *Dilepton and Four-Lepton Signals at the LHC in the Littlest Higgs Model with T-parity Violation,* Journal of High Energy Physics **05**, 001, (2010)

Preprints:

1. A. Nyffeler, *Hadronic light-by-light scattering contribution to the muon $g-2$,* arXiv:1001:3970 [hep-ph] (to appear in Chinese Physics C)

Conferences/Workshops Attended:

1. *6th International Workshop on Chiral Dynamics*, Bern, Switzerland, July 2009
   Talk: Hadronic light-by-light scattering in the muon $g-2$: a new short-distance constraint on pion exchange
2. *International Workshop on e^+e^- Collisions from Phi to Psi*, Beijing, China, October 2009
   Talk: Hadronic Light-by-Light Scattering Contribution to the Muon $g-2$
3. *Conference on Data to Theory at the LHC*, Shimla, December 2009
4. *XIth Workshop on High Energy Physics Phenomenology (WHEPP-XI)*, Ahmedabad, January 2010

Visits to other Institutes:

1. Centre de Physique Théorique (CPT), Marseille, France, May 2009 (3 days)
2. Instituto de Física Corpuscular (IFIC), Valencia, Spain, June 2009 (3 days)
3. Departamento de Fisica Teorica y del Cosmos, Universidad de Granada, Spain, June 2009 (3 days)
4. Institute for Theoretical Physics, Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland, June 2009 (1 day)

5. Groupe de Physique Théorique, Institut de Physique Nucléaire (IPN), Orsay, France, June 2009 (2 days)
6. Institute of Theoretical Physics, University of Bern, Switzerland, June - July 2009 (5 days)
7. Laboratori Nazionali di Frascati (LNF), Italy, February 2010 (5 days)

Invited Lectures/Seminars:

1. *The Hadronic Light-by-Light Scattering Contribution to the Muon $g-2$*, CPT, Marseille, France, May 2009
2. *The Hadronic Light-by-Light Scattering Contribution to the Muon $g-2$*, IFIC, Valencia, Spain, June 2009
3. *The Hadronic Light-by-Light Scattering Contribution to the Muon $g-2$*, Universidad de Granada, Spain, June 2009
4. *The Hadronic Light-by-Light Scattering Contribution to the Muon $g-2$*, IPN, Orsay, France, June 2009
5. *Theory of the muon $g-2$: some recent developments*, LNF, Frascati, Italy, February 2010

Other Activities:

1. Together with V. Ravindran, Rahul Basu (IMSc, Chennai) and Prakash Mathews (SINP, Kolkata), I am on the Organizing Committee for an "Advanced School on Radiative Corrections for the LHC" in April 2011 and the "10th International Symposium on Radiative Corrections - RADCOR 2011" in September 2011. Our detailed proposal to host RADCOR 2011 in India was approved by the International Advisory Board of this series of symposia. We also succeeded to obtain generous funding from the International Centre for Theoretical Sciences (ICTS), TIFR, Mumbai. We are now planning in detail the Advanced School and the RADCOR Symposium (choice of venues, program, lecturers). August 2009 - March 2010 (and continuing).
2. Pheno lunch talk: Theoretical Constraints on the Higgs Effective Couplings (based on arXiv:0907.5413 [hep-ph]), August 2009
3. Talk at HRI Symposium: Applying effective field theory methods to the muon $g-2$ and to new physics at the LHC, September 2009
4. I supervised 3 Visiting Students on an "Introduction to Quantum Mechanics", September - October 2009

Suvrat Raju

My research work this year focused on understanding the structure of scattering amplitudes in gauge theories and gravity. Recent work has shown that these amplitudes have remarkable structure that is difficult to see from the Lagrangian; understanding this structure better might give us new insights into quantum field theory.

However, most work in this direction has focused on $\mathcal{N} = 4$ supersymmetric Yang-Mills theory (SYM). This theory seems to have the nicest scattering amplitudes, of all gauge theories, despite having a very complicated Lagrangian. Together with Shailesh Lal, I addressed the question of whether other gauge theories also see similar simplifications in their S-matrices. We found a set of gauge theories coupled to matter, whose gluon scattering amplitudes, at one-loop, were as simple as those of $\mathcal{N} = 4$ SYM. We also classified other gauge theories that saw simplifications, albeit to a lesser degree than $\mathcal{N} = 4$ SYM, in their S-matrices. Hence, our study gave us a classification of the next-to-simplest quantum field theories.

Publications:

1. Shailesh Lal and Suvrat Raju, *The Next-to-Simplest Quantum Field Theories* , Phys.Rev.D **81**, 105002, (2010)

Preprints:

1. Shailesh Lal and Suvrat Raju, *Rational Terms in Theories with Matter,* arXiv:1003.5264, HRI-ST-1005

Conference/Workshops Attended:

1. *IPM School and Workshop*, Iran, April 2009.
2. *Strings 2009*, Italy, June 2009.
3. *5th Regional Meeting on String Theory*, Greece, June, 2009.
4. *National Strings Meeting*, India, February 2010.

Visits to other Institutes:

1. Tata Institute of Fundamental Research, Mumbai, India, March – June 2009.
2. Institute of Physics and Mathematics, Tehran, Iran, April 2009.
3. National Institute for Science Education and Research and Institute of Physics, Bhubaneshwar, India, August 2009.
4. Tata Institute of Fundamental Research, Mumbai, India, November 2009.
5. Indian Institute for Science Education and Research, Bhopal, India, November 2009.

6. Indian Institute of Technology, Mumbai, India, November 2009.

Invited Lectures/Seminars:

1. *On-Shell Methods for Quantum Field Theories*, IPM School and Workshop, Institute of Physics and Mathematics, Tehran, Iran, April 2009.
2. *On-Shell Methods for Quantum Field Theories*, Research seminar, Institute of Physics, Bhubaneshwar, August 2009.
3. *Black Holes and the Gauge Gravity Conjectures*, Institute Colloquium, National Institute of Science Education and Research, Bhubaneshwar, August 2009.
4. *The Next to Simplest Quantum Field Theories*, Theory Colloquium, Tata Institute of Fundamental Research, Mumbai, November 2010.
5. *The Next to Simplest Quantum Field Theories*, Research Seminar, Indian Institute of Science Education and Research, Bhopal, November 2010.
6. *Black Holes and the Gauge Gravity Conjecture*, Feynman Club Lecture, St. Stephen's College, Delhi, December 2010.
7. *Scattering Amplitudes in Gauge Theories and Gravity*, National Strings Meeting, Mumbai, February 2010.

Academic recognition/Awards:

- Ramanujan Fellowship, Department of Science and Technology, February 2010.

Prabhu Ramappa

I am interested in the broad research area of **Quantum Information Theory** which is a new fledgling field. Quantum information theory has its implications in many information processes like quantum computation and quantum communication. *Quantum Entanglement* or quantum correlation is identified as a key resource for many of these quantum information processes. Before joining to Harish-Chandra Research Institute, Allahabad, I worked on theoretical characterization and quantification of entanglement in two-qubit and symmetric multiqubit systems using non-local invariants, covariance matrix technique and q-conditional entropy. I also studied non-classicality of quantum states, like photon added coherent and thermal states, using entanglement potential, Wigner function and other non-classicality measures.

After joining Harish-Chandra Research Institute, Allahabad on 17th February 2010, I, along with Dr. Aditi Sen De and Dr. Ujjwal Sen have started studying a new entanglement characterization for finite dimensional quantum systems, motivated by techniques known in infinite dimensional quantum systems. Also, I have started working on spin systems in order to study possible characterization of quantum entanglement in such multi particle systems.

Abhijit Samanta

We have analysed atmospheric neutrino oscillation data for a magnetized iron calorimeter detector (ICAL) proposed at the India-based Neutrino Observatory (INO) considering the muons (which are directly measurable with high resolution). In this type of detector, one can separate neutrinos and antineutrinos due to the magnetic field. Here, we have estimated the sensitivities of ICAL detector to neutrino mass hierarchy and oscillation parameters. We have also explored the possibilities to probe non-standard physics like long-range leptonic forces and CPT violation.

Publications:

1. A. Samanta, *Prospects of measuring the leptonic CP phase with atmospheric neutrinos,* Phys. Rev. D **80**, 073008 (2009).
2. A. Samanta, *Sensitivity to neutrino mixing parameters with atmospheric neutrinos,* Phys. Rev. D **80**, 113003 (2009).
3. R. Gandhi, A. Samanta and A. Watanabe, *The Role and Detectability of the Charm Contribution to Ultra High Energy Neutrino Fluxes,* JCAP **0909**, 015 (2009).
4. A. Samanta, *The discrimination of mass hierarchy with atmospheric neutrinos at a magnetized muon detector,* Phys. Rev. D **81**, 037302 (2010).

Preprints:

1. A. Samanta, *Long range forces, oscillation parameters and mass hierarchy with atmospheric neutrinos at a magnetized muon detector,* arXiv:1001.5344 [hep-ph]
2. A. Samanta, *Probing CPT violation in neutrino oscillation: A three flavor analysis,* arXiv:1005.4851 [hep-ph]

Conference/Workshops Attended:

1. *"NuGoa09" on "Aspects of Neutrinos",* Goa, April 2009.
2. *INO Collaboration meeting,* Panjab University, Chandigarh, November 2009.
3. *Workshop on High Energy Physics Phenomenology (WHEPP XI),* Physical Research Laboratory, Ahmedabad, January 2010.
4. *Nu HoRIzons III,* Harish-Chandra Research Institute, Allahabad, February 2010.

Invited Lectures/Seminars:

1. *Sensitivity to neutrino mixing parameters with atmospheric neutrinos at INO,* "NuGoa09" on "Aspects of Neutrinos", Tata Institute for Fundamental Research, Goa, April 2009.

2. *"Role of atmospheric neutrinos in future neutrino oscillation experiments,* INO Collaboration meeting, Panjab Univeristy, Panjab, November 2009.
3. *"Atmospheric neutrinos in future neutrino oscillation experiments,* Nu HoRIzons III, Harish-Chandra Research Institute, Allahabad, February 2010.
4. *Recent issues in neutrino oscillation experiments with atmospheric neutrinos,* IISER Mohali, Mohali, Panjab, February 2010.

Santosh Kumar Singh

The fermion masses and mixing data provides a very important probe to understand Yukawa sector of Standard Model. While quark mixing angles are very small, the mixing angles in the leptonic sector are substantially large. Moreover, the mass scale of neutrinos is much suppressed compared to the mass scale of charged fermions in the Standard Model. The natural suppression of neutrino masses is explained by the elegant seesaw mechanism by introducing a lepton number violating term at some high scale. The seesaw mechanism comes in various versions (Type I, Type II, Type III, Type I+II, Inverse, Linear) depending on the fermion and Higgs content in the given model.

Type I+II seesaw structure naturally emerges in Left-Right symmetric and SO(10) Grand Unified models. The observed small neutrino masses (eV) demands the new physics scale around 10^{11} GeV which is beyond the reach of current collider experiments. However, some kind of cancellation between the Type I and Type II term can provide a hope to bring down the new physics scale. We are exploring possibility of such mechanism in SO(10) models.

One of the interesting aspects of Grand Unified models is that they provide a framework where one can expect relation between masses and mixing parameters of lepton and quark sector. The case is not so supportive for the Inverse seesaw structure in the SO(10) Grand Unified models. However, the structure becomes predictive if one embeds this in E6 Grand Unified framework. We are trying to explore such predictive seesaw structure in E6 Grand Unified models.

Conference/Workshops Attended:

1. *Nu HoRIzon III*, HRI, Allahabad, India, February 8-10 2010
2. *Workshop On High Energy Physics Phenomenology*, PRL, Ahmedabad, India, January 2-10 2010.

Joint Colloquia

1. Bozena Czerny: Active Galactic Nuclei-are they important?
2. S. Kesavan: Isoperimetric inequalities.
3. Soumen Roy: Networks and emergence.
4. M. Waldschmidt: Number Theory Challenges of 21st century.
5. K. Sridhar: Spissitudinal Explorations.
6. Aninda Sinha: Ads/CFT and the strongly coupled quark gluon plasma.
7. Carlos Florentino: Geometry and topology of moduli spaces of representations.
8. Bruce Mellado: The start of LHC era: first collisons and discovery potential.
9. Ashok Das: Effective actions at finite temperature.
10. Swarnali Bandhopadhyay: Charge and spin transport in mesoscopic systems.
11. Sanjeev Dhurandhar: Gravitational Waves: A Challenge.
12. Ritesh Singh: A bottom up approach to new physics at colliders.
13. Utpal Sarkar: Astroparticle Physics, LHC and neutrinos.
14. Subhashish Banerjee: Dynamics of entanglement in open quantum systems.
15. Golam M Hossain: Driving cosmic inflation on a bumpy road.
16. Romesh K Kaul: Is there a vacuum structure in quantum gravity?
17. Indira Chaudhari: Initial stage of growth of single-walled carbon nanotubes: Modelling and simulations.
18. M Ram Murty: Ramanujan and the Zeta Function (A popular talk)
19. Sankhasubhra Nag: Quantum Chaos: Dynamical features.
20. M Sami: Understanding the late time cosmic acceleration.
21. Ajit Srivastava: Super-horizon fluctuations in CMBR and in relativistic heavy-ion collisions.
22. Rajib Saha: Estimating CMBR angular power spectrum.
23. S N Tripathi: Understanding atmospheric haze.
24. HRI Symposium.

Mathematics Talks and Seminars

1. Basudeb Datta: A natural triangulation of complec projective plane
2. Mahender Singh: The Well's map and automorphisms of abelian group extensions.
3. M. Waldschmidt: History of irrational and trancendental numbers.
4. Zhi-Wei Sun: Problems and results in additive combinatorics.
5. W. Kohnen: An introduction to Siegel Modular Forms.
6. Pavinder Singh: Nearly Extremal Cohen-Macaulay and Gorenstein algebras.
7. Pradip Kumar: The Frobenius Theorem.
8. Pradeep Kumar: Isoclinism of groups and its usefulness.
9. Kasi Viswanadham: Dirichlet's Prime Number Theorem.
10. Jay Mehta: Introduction to Elliptic Curves.
11. Akhilesh P: On Eigen functions of hyperbolic laplacian.
12. Sandeep Repaka: The splitting of primes in quadratic extensions.
13. Sudhir Pujahari: The Liouville's Theorem and its extensions.
14. Jacob Mostovoy: Power series expansions for groups and knots.
15. Jie Wu: The link invariants given by homotopy groups.
16. Subhash S Bhoosnurmath: Differential Geometric complex analysis.
17. M Ram Murty: Trancendence of cetain infinite series.
18. Vivek Kumar Jain: Transversals in groups.
19. Vivek Kumar Jain: On finite nilpotent groups and JND groups.
20. Moharram Khan: A study of derivations in certain rings and near rings.
21. P K Ratnakumar, Rukmini Dey: Discussion meeting on geometry and analysis.
22. S D Adhikari, R Thangadurai, N Raghavendra: Discussion meeting on Finite Fields and Coding Theory.
23. Summer Programme in Mathematics.

Physics Talks and Seminars

1. Ayan Mukhopadhyay: Non-Equilibrium aspects of Gauge/Gravity Duality.
2. Shamik Banerjee: Spectrum of Dyons in $N = 4$ String Theory.
3. Ram Iyer: String Theory and Water Waves.
4. Arjun Bagchi: The non relativistic limit of Ads/CFT.
5. Shinji Shimasaki: Large N reduction on group manifolds and coset spaces.
6. Jaiswal Nagar: Magnetocaloric effect and magnetic cooling near a field-induced quantum critical point.
7. Rajesh Gopal: Effect of magnetic fields on the conversion of neutron star to quark star.
8. Yogesh Srivastava: Saving the black hole.
9. Satyajit Banerjee: Low frequency, large amplitude, velocity, fluctuations and noveldynamics of the driven vortex state.
10. Jerome Martin: Amplification of small scale density perturbation during preheating in single field inflation.
11. Partha Nag: Chiral symmetry breaking in an intersecting brane model.
12. H. Zeen Devi: Phenomenology of neutrino mass matrices obeying $\mu - \tau$ symmetry and leptogenesis.
13. Jaswant K. Yadav: Scale of homogeneity.
14. William H. Kinney: Where do primordial perturbations come from?
15. Saurav Chatterjee: Dynamical evolution of dense star clusters: Challenges and Successes.
16. Pooja Srivastava: Double-occupancy effects on electronic excitations and band-gap renormalization in an antiferromagnet.
17. Emmanuel Rollinde: Nucleosynthesis constraints on cosmology.
18. Akitsugu Miwa: GCA in $2d$.
19. Nikos Irges: A new model for confinement.
20. Sandipan Sengupta: Quantum realizations of Hilbert-Palatini second class constraints.
21. Suvraj Raju: A Duality for the S matrix.
22. Ritesh K. Singh: In model independent spin analysis and some SUSY forecast for LHC.
23. Golam M Hossain: Reliable predictions from quantum gravity corrected cosmology?
24. Satoshi Nawata: LHC phenomenology for string hunters.
25. Indira Chaudhari: Ab initio determination of ion traps and the dynamics of silver in silver- doped chalcogenide glass.
26. Ayan Mukhopadhyay: What Louville CFT can tell us about certain $N = 2$ SUSY gauge theories?
27. Manjari Bagchi: Effects of stellar interactions on orbital parameters of binary radio pulsars in globular clusters.
28. Suvrat Raju and Shailesh Lal: The next-to-simplest quantum field theo-

ries.

29. N D Hari Dass: Super-universality in effective string theories.
30. Indranath Bhattacharya: Dynamics of the collective oscillations of supernova neutrinos.
31. S G Rajeev: Topological solitons in the little Higgs Model can be dark matter.
32. Sashideep Gutti: Quantum Gravitational collapse in the Lemaitre-Tolman-Bondi model with a positive cosmological constant.
33. Rajib Saha: CMBR angular power spectrum estimation using blind and nonblind methods.
34. Kanan K Datta: The optimal redshift for detecting ionized bubbles in HI 21-cm maps.
35. Shadab Alam: Transport in some mesoscopic systems.
36. J S Bagla: The hyperfine transition of ^{3}He II as a probe of the intergalactic medium.
37. Alok C Gupta: Multi-wavelength studies of active galactic nuclei (AGNs) and Gamma-Ray Bursts (GRBs).
38. Sourav Sur: Cosmic (super-) acceleration in the realm of kinetically interacting double quintessence.
39. Sudipta Das: Non-Minimal quintessence with nearly flat potential.
40. Moitri Maiti: Transport properties in Graphene junctions.
41. J S Bagla, T Roy Choudhury, Girish Kulkarni, Ananthi R: Cosmological Reionization.

Conferences/Schools/Meetings Organized

Mathematics

1. Discussion Meeting on Finite Fields and Coding Theory; 2-14 Nov 2009 at HRI.
2. Discussion Meeting on Geometry and Analysis; 20 Jan- 2 Feb 2010 at HRI.
3. SPIM 2009; 1- 19th June 2009.

Physics

String Theory Project

1. Indian String Meeting ; February 9-15 2010 at IIT, Mumbai.

Neutrino Project

1. Nu HoRIzons III; February 7-9 2010 at HRI.

RECAPP

1. Data to Theory Approach at the LHC; December 16-2009 at IIAS, Shimla.
2. Prof. B. Mellado (lecture series) January 7-14 2010 at HRI.

Astrophysics Project

1. International Conference on Cosmological Reionization ; February 16-20 2010 at HRI.

Recent Graduates

1. **Jayanti Prasad**, *Aspects of Gravitational Clustering,* Allahabad University; November 5, 2009.
2. **Nabamita Banerjee**, *Different Aspects of Black hole Physics in String Theory*, Homi Bhabha National Institute; October 23, 2009.
3. **Rajeev Kumar Jain**, *On the Origin and Evolution of Perturbations in the early universe*, Homi Bhabha National Institute; October 23, 2009.
4. **Anurag Tripathi**, *Higher Order QCD Radiative Corrections to processes at the Large Hadron Collider,* Homi Bhabha National Institute; Viva voce held on February 2, 2010.
5. **Supriya Arvind Pisolkar,** *Norm Maps in Extension of Local Fields and Applications,* Homi Bhabha National Institute; Viva voce held on February 12, 2010.
6. **Mahender Singh** *Cohomology of orbit spaces, fixed point sets of group actions and parametrized Borsuk-Ulam problem,* Homi Bhabha National Institute; Viva voce held on March 23, 2010.
7. **Kalpataru Pradhan**, *The impact of B site Disorder in the Manganites*, Homi Bhabha National Institute; November 19, 2009.
8. **Priyotosh Bandopadhyay**, *Some Studies on Higgs searches at the Large Hadron Collider in Scenarios Beyond the Standard Model,* Homi Bhabha National Institute; February 6, 2010.
9. **Arijit Saha**, *Electron-electron interaction effects on transport through mesoscopic hybrid junctions,* Homi Bhabha National Institute; Novemver 19, 2009.

Publications

Sukumar Das Adhikari

1. Sukumar Das Adhikari, Sanoli Gun and Purusottam Rath, *Remarks on some zero-sum theorems,* Proc. Indian Acad. Sci. (Math. Sci.) **119, No. 3**, 275–281, (2009).
2. Sukumar Das Adhikari and Andrew Granville, *Visibility in the plane,* J. Number Theory **129, Issue 10**, 2227–2646, (2009).
3. Sukumar Das Adhikari, A. A. Ambily and B. Sury, *Zero-sum problems with subgroup weights,* Proc. Indian Acad. Sci. (Math. Sci.), **to appear**.

Sanjaykumar Hansraj Amrutiya

1. S. Amrutiya and I. Biswas, *On the F-fundamental group scheme,* Bull. Sci. Math. (2009), doi:10.1016/j.bulsci.2009.12.002, in press.

Punita Batra

1. Punita Batra, Xiangqian Guo, Rencai Lu, Kaiming Zhao, *Highest weight modules over pre-exp-polynomial Lie algebras,* Journal of Algebra, **322**, 12(2009), 4163-4180.
2. Tanusree Pal, Punita Batra, *Representations of graded multiloop Lie algebras,* Communications in Algebra, **38**, 1(2010), 49-67.

Kalyan Chakraborty

1. Kalyan Chakraborty and Florian luca, *Perfect powers in solutions to Pell equations,* Revista Columbiana de Mathematicas **43**, 71–86, (2009)
2. K. Chakraborty, S. Kanemitsu and T. Kuzumaki, *Finite expressions for higher derivatives of the Dirichlet L-function and the Deninger R-function,* Hardy-Ramanujan Journal **32**, 38–53, (2009)
3. K. Chakraborty, S. Kanemitsu, J. -H. Li and X. -H. Wang, *Manifestations of the Parseval identity ,* Proc. Japan Acad.**85**, 149–155, (2009)
4. K. Chakraborty, S. Kanemitsu and H. -L. Li, *On the values of a class of Dirichlet series at rational arguments,* Proc. Amer. Math. Soc. **138**, 1223–1230, (2010)

5. K. Chakraborty, S. Kanemitsu, H. Kumagi and Y. Kubara, *Shapes of objects and the golden ration,* Journal of Sangluo Univ. **23**, 18–27, (2009)
6. Kalyan chakraborty, Shigeru Kanemitsu and Haruo Tsukada, *Vistas of special function II,* World Scientific (2010)

Chandan Singh Dalawat

1. Chandan Singh Dalawat, *Local discriminants, kummerian extensions, and elliptic curves,* Journal of the Ramanujan Mathematical Society **25** 1, 25–80, (2010)
2. Chandan Singh Dalawat, *Congruent numbers, elliptic curves, and the passage from the local to the global,* Resonance **14** 12, 1183–1205 (2009). [This paper was also listed in 2006–7, but the publication for which it was destined never appeared.]
3. J. Coates, C. S. Dalawat, A. Saikia and R. Sujatha (editors) *Guwahati workshop on Iwasawa theory of totally real fields*, 185 pp., Ramanujan Mathematical Society Lecture Notes (2010)

Rukmini Dey

1. Rukmini Dey, *Erratum: Geometric prequantization of the moduli space of the vortex equations on a Riemann surface,* Journal of Mathematical Phys. **50**, 119901, (2009)

Vivek Kumar Jain

1. Vivek Kumar Jain, *On odd order nilpotent group with class 2,* Arch. Math. **94**, 29-34, (2010)

Jaban Meher

1. W.Kohnen and J. Meher , *Some remarks on the q-exponents of generalized modular functions,* The Ramanujan Journal,(To appear).

B. Ramakrishnan

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About the Computer Section

1. Newer versions of different flavors of Linux operating systems were loaded on the desktops.
2. Internet bandwidth through Sify Ltd. was upgraded to 10 Mbps in view of the increased Internet usage.
3. 16 Mbps broadband Internet bandwidth through Reliance Communications was upgraded to 22 Mbps. A reliable proxy server on this link was set up for the users.
4. A new webmail server for the Institute was set up for the Institute e-mail users.
5. New internal mail server and domain name server were set up.
6. Computing related to conferences were held in the conference computer room.
7. New versions of several applications software were loaded on users' systems, computer centre and conference room systems.
8. All the computer centre NIS client machines were upgraded with Ubuntu (LTS).
9. Two 100 KVA ONLINE central UPS with parallel redundancy (N+1) was installed and commissioned to provide redundant UPS power supply to all computers, peripherals and networking equipments within the Institute building.
10. Expansion of wireless networking to cover up most of the places of Institute building and library building has been done.

Current activities and plans

1. Purchase order for the up-gradation of existing Local Area Network with Optical Fiber Cable Giga backbone and with Gigabit node connectivity has been released.
2. Purchase order for up-gradation of existing file server with high end Network Storage Systems (NAS) with redundancy and automated backup facility has been released.
3. Purchase of a few high end mono laser printers is being processed.
4. Up-gradation of Institute's Mail Server, Name Server, Web Server, and firewall servers are likely to be done.

Library

The Institute's library is one of the best-equipped libraries in the region. Being a research oriented institute, it provides the required support to the academic and research activities. It remains open on all working days between 8 a.m. to 2 a.m. including Saturdays. It also remains open during Sundays and the Gazetted holidays between 10 a.m. to 6 p.m. In 2009-10 it had added 1362 (One thousand three hundred sixty two) books, this increased the total number of books to 19249 (Nineteen thousand two hundred forty nine) which includes 677 books as gifted ones. It also added 1794 bound volumes of the journals during the period from 1st April 2009 to 31st March 2010, this has increased bound volumes collection to 32928. The institute's library has a total collection of 52177 (Fifty two thousand one hundred seventy seven) of books and bound volumes. The library also subscribed to 225 journals during this period. It includes 110 as online journals.

The physical stock verification has been recently completed with the help of PDT (Portable Data Terminal) for collection of Bar Codes, since the whole collection is Bar Coded and equipped with Tattle Tapes for security, no loss of titles in books or journals was found.

During the last year basic emphasis had been to provide more space for users. We have shifted some of the less used back volumes to the first floor storage area and created some more reading space for the users through rearranging of the book and back volume display racks. We provided better systems to our users for browsing the library OPAC and related search. We procured one more photocopying machine to provide better photocopying services. We inducted one library trainee to provide training in library activities and provide better library services to our users under the XIth plan Library Development Project. We enriched our Building of the Digital Depository of the HRI, which includes the submitted articles, thesis, lectures etc. The library web page has been updated which provides more detailed information about the library such as subscribed databases, archives, library rules, library staff, list of online journals, online link to the Video lectures and other useful links. The emphasis was also given to procure maximum number of journals on line. We have been providing on-line access of the periodical to our users for 110(One hundred ten) titles.

We have provided the Web Enabled library catalogue to our users. The li-

brary can be termed as a completely automated library system, which includes acquisition, cataloguing, circulation, search modules etc. This on-line catalogue had increased the opportunities of the use of our library resources by the neighboring organizations such as INSDOC, TIFR etc. through the Document Delivery Services (DDS). Normally we provide the DDS on request through post, at a very nominal cost, but requests had also been honoured through e-mail. We had encouraged the use of the library by providing the library consultation facilities to the research scholars from the neighboring institutes. We had strengthened our library security with the implementation of Electro-magnetic Tattle Tapes to reduce the losses. It has been made completely functional.

Construction Work

1. Tender for Construction of Hostel, Extension of Institute Building, Library, Computer Centre, Engineering building and Community Centre Annexe at HRI has been issued to the short-listed parties after prequalification of contracting agencies. The technical bid has been opened and necessary exercise for opening of financial bid is under progress.
2. The work for 33KV uninterrupted power supply line from 132KV substation by UPPCL and other associated works under the scope of HRI have been completed. The 33KV power line has been energised.
3. Following miscellaneous works were also carried out during the financial year :
   - Electrical & Air conditioning works related to Upgradation of UPS room.
   - Supply & fixing vertical blinds in pantry.
   - Fencing for 33KV switchyard.
   - Conductive and antistatic flooring in Cluster room.
   - Renovation of toilets in Hostel-1.
   - Attachment of servant quarters to main unit in old type E houses.
   - Parking shed near Hostel-1 building.