Academic Report 2010–11

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 institutes 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 took over as Director from July 19, 2005 to May 15 2011. The Institute will soon have a new director. 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 computation, 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 stan-

dard model is done in high-energy phenomenology. The Institute is a member of the India-based Neutrino Observatory (INO) collaboration. Research in quantum information and computation includes quantum algorithms, quantum communication, quantum cryptography, theory of entanglement and other nonclassical correlations, quantum dynamical maps, foundations of quantum mechanics, geometric phases, information processing in the presence of closed time-like curves, the recently developing field at the interface of quantum many-body physics and quantum information, and other related issues.

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

This 2010-11 Anuual Report of Harish-Chandra Research Institute (HRI) is intended to provide a glimpse of the Institute, especially of the academic accomplishments in the past year. The Institute, with a focus on mathematics and theoretical physics, is internationally renowned and is generously funded by the Department of Atomic Energy (DAE) of the Government of India.

HRI trains students who join after an M.Sc. (or a B.Sc.) for a Ph.D. (integrated Ph.D.) programme. They are selected via a rigorous procedure to attract only the best. For example, in physics, the high-rankers in the JEST examination are invited to appear in a written test and interview, for selection. Only a small fraction get through. All students register with the Homi Bhabha National Institute for their Ph.D. On completion of their degrees, they are picked up by leading institutions, usually abroad, with post-doctoral offers. Afterwards, they are absorbed in the top research and teaching institutions in the country.

Over the years, the Institute has made a concerted effort to enhance the student intake without making any compromise on high quality. The current student strength – around 60 – is being housed in two hostels, a married student apartment block, and from last year, in rented rooms in the city of Allahabad. A third hostel which should be able to accommodate another 60 students is under construction in the HRI campus. The Foundation Stone for this hostel will soon be laid by the Chairman, Atomic Energy Commission.

HRI has also emerged as a thriving hub for collaboration meetings, pedagogic schools, and focussed conferences. The locational advantage of a well-equipped centre in a peaceful non-urban setting, excellent support facilities and most importantly the high quality scientists present locally makes the Institute a popular venue. Like every year, this year there were meetings in mathematics and physics covering a wide range – summer training courses for M.Sc. students to frontier research meetings and schools with wide national and international participation.

Besides the new students' hostel, work is now going on to extend the li-

brary building to increase, among other things, reading room and library storage space, provide more floor area to the Computer Centre, etc. These constructions are now on in full-swing. In addition, the ever-increasing number of short- and long-term visitors as also the regular scientific meetings necessitates an extension of the Guest House. This, and a new Conference Centre Complex, are on the cards.

Needless to say, one must bear in mind that the Institute is located not in a metropolis. Hence infrastructural support is of essence for it to succeed. The electrical power connection to the Institute is via an overhead line. On occasions, especially in the time of stormy weather, there have been breaches in the connection. For the essential services like the cluster computers, the internet links, etc., as a back-up two 500kVA DG sets have been installed in the past year. These will suffice at the time of power disruptions.

The lifeline of a research institute, that too in an isolated location, is its internet linkage to the world. Keeping this in mind the Institute internet connection bandwidth has been enhanced every year and now stands at more than 60 Mbps. Several service providers are utilised to build up redundancy.

HRI continues to keep Outreach as one of its missions. Several faculty members participate in INSPIRE and other programmes to act as Resource Persons for the students. The Institute also organises a Talent Search Test for physics and mathematics students in class X and XII of the city of Allahabad. This Test has been a continuing success and the prize-winners have gone on to do very well in later life and in competitions like the international olympiads.

During the last year one HRI-Triveni Lecture and three HRI-Girdharilal Mehta Lectures were arranged. Professor Vladimir Voevodsky of the Institute for Advanced Study, Princeton, USA delivered the 5th HRI-Triveni Lecture entitled 'Mathematics and Computers' on 16th February 2011. On 19th July 2010 the 9th HRI-Girdharilal Mehta Lecture on 'A Review of the Indo-US nuclear agreement and its ramifications' was delivered by Professor R. Rajaraman, JNU. Professor Boris Kayser, Fermilab, USA spoke on 'Antimatter, matter and how we came to be' in the 10th HRI-Girdharilal Mehta Lecture on February 21, 2011. The 11th HRI-Girdharilal Mehta Lecturer was Professor Kaoru Hagiwara, KEK, Japan, who spoke on March 08, 2011 on 'Physics to be explored at the LHC'.

As in the past years, there has been some changes in the staff at the Institute. Dr. Arun K. Pati, whose expertise is in Quantum Information, has joined the Institute. Earler, he was at the Bhabha Atomic Research Centre, Mumbai. Dr. Srubabati Goswami, has left the Institute to join the Physical Research Laboratory, Ahmedabad. Dr. Jasjeet Singh Bagla and Dr. L. Sriramkumar have been granted lien to take up positions at IISER, Mohali and IIT Madras, Chennai, respectively. Mr. Sanjeev Nagar has joined as the Hindi Typist. The Stores and Purchase Officer of HRI, Mr. P.S. Babu, has left the Institute.

HRI scientists have continued to win laurels for their academic work. Over the past year Professor Sudhakar Panda was elected to the Fellowship of the National Academy of Sciences, India. Dr. Andreas Nyffeler was selected for the 2010 Heinrich Greinacher award by the University of Berne, Switzerland.

As always, the non-academic staff of the Institute have worked hard to ensure that the prestige of HRI is enhanced. Many of them have gone out of their way to see to it that the faculty, visitors, and students can perform their work without any hindrance. There is a strong feeling of affiliation and identification with the organisation.

HRI is on a forward moving epoch. The general atmosphere is upbeat. We can expect many further successes in the period ahead.

A. RAYCHAUDHURI
DIRECTOR

List of Governing Council Members

(2010 -11)

1. Prof. M.S. Raghunathan
   (Chairman, Governing Council HRI)
   School of Mathematics
   Tata Institute of Fundamental Research
   Homi Bhabha Road,
   MUMBAI - 400 005

2. Prof. R. Balasubramanian
   Director
   Institute of Mathematical Sciences
   CIT Campus, Taramani,
   CHENNAI - 600 113

3. Dr. J.N.De,
   BH-135, Sector-II
   Salt Lake
   KOLKATA - 700 091

4. Prof. Narendra Kumar
   Raman Research Institute
   C.V. Raman Avenue,
   Sadashivanagar
   Bangalore - 560 080

5. Prof. H.S.Mani
   2, Fourth Cross Street
   Durga Colony, Sembakkam
   CHENNAI - 600 073

6. Shri S.L. Mehta
   4, Clive Row
   KOLKATA - 700 001

7. Shri Avnish Mehta
   4, Penn Road,
   KOLKATA- 700 027

8. Shri Rama Kant Misra,IAS (Retd.) 22 / 1E, P.C. Banerjee Road
   Allen Ganj
   ALLAHABAD - 211002

9. Director, Higher Education, U.P.
   Near G.P.O, Civil Lines,
   ALLAHABAD - 211 001

10. Prof. Amitava Raychaudhuri, Director
    Harish-Chandra Research Institute
    Chhatnag Road, Jhunsi,
    Allahabad- 211019

11. Shri V.R.Sadasivam
    Joint Secretary (F)
    Govt. of India,
    Deptt. of Atomic Energy,
    Chhatrapati Shivaji Maharaj Marg,
    MUMBAI - 400 001

12. Ms. Revathy Iyer
    Joint Secretary (R & D),
    Govt. of India,
    Deptt. of Atomic Energy,
    Anushakti Bhavan,
    Chhatrapati Shivaji Maharaj Marg,
    MUMBAI - 400 001

ACADEMIC STAFF

Faculty Members (Mathematics)

1. Prof. S.D. 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. Ratnakumar PK
11. Dr. Manoj Kumar
12. Dr. Gyan Prakash

Faculty Members (Physics)

1. Prof. B. Mukhopadhyaya
2. Prof. S. Naik
3. Prof. Sudhakar Panda
4. Prof. Raj Gandhi
5. Prof. Ashoke Sen
6. Prof. Sumathi Rao
7. Prof. Dileep Jatkar
8. Prof. Pinaki Majumdar

9. Prof. V. Ravindran
10. Prof. Rajesh Gopakumar
11. Dr. L. Sriramkumar
12. Dr. T. P. Pareek
13. Dr. Prasenjit Sen
14. Dr. Tapas Kumar Das
15. Dr. Aseshkrishna Datta
16. Dr. Sandhya Choubey
17. Dr. Tirthankar Roy Choudhury
18. Dr. Ujjwal Sen
19. Dr. Aditi Sen De
20. Dr. G.Venketeswara Pai
21. Dr. Arun Kumar Pati
22. Dr. Anirban Basu

Administrative Staff

1. Shri P.B. Chakraborty [Registrar]
2. Shri Rajkumar Gulati [Accounts Officer]
3. Dr. Vijay Raghav Tiwari [Librarian]
4. Shri Manish Sharma [Scientific Officer 'C']
5. Shri Amit Roy [Internal-Audit-cum Administrative officer]
6. Shri Sanjai Verma [System Manager Secretary]
7. Shri Prabhat Kumar [Senior Private Secretary]
8. Shri K.S. Shukla [Professional Assistant]
9. Shri A.K. Srivastava [Jr. Engineer (Electrical)]
10. Shri V.K. Srivastava [Jr. Engineer (Civil)]
11. Shri Jagannath Yadav [Accountant]
12. Shri R.P. Sharma [Manager Guest House]
13. Ms. Archana Tandon [Office Superintendent]
14. Ms. Anju Verma [Scientific Assistant]
15. Shri U.K. Dwivedi [Cashier]
16. Shri D. Malhotra [Upper Division Clerk]
17. Shri K.K. Srivastava [Upper Division Clerk]
18. Shri Yashpal Singh [Stenographer]
19. Ms. Sumitra [Upper Division Clerk]
20. Ms. Seema Agarwal [Receptionist]
21. Mr. Om Kumar Karn [Junior Hindi Translator]
22. Shri P.N. Mishra [Jr. Lib. Assistant]
23. Shri D.P. Sharma [Jr. Lib. Assistant]

24. Shri Sanjeev Nagar [Hindi Typist]
25. Shri D.N. Dubey [Bearer (Canteen Cadre)]
26. Shri Lalloo Ram [Bearer (Canteen Cadre)]
27. Shri Kamlesh Thakur [Bearer (Canteen Cadre)]
28. Shri R.K. Dixit [Peon/Watchman]
29. Shri Kamta Prasad [Peon/Watchman]
30. Shri Rajesh Kumar [Sweeper]
31. Shri Munna Lal [Gardener]

Visiting Fellow

Mathematics

1. Dr. Geeta
2. Dr. Ashish Gupta
3. Dr. Rajesh Kumar Srivastava
4. Dr. Saurabh Kumar Srivastava
5. Dr. Rajat Kanti Nath
6. Dr. Ashwin S. Pande

Physics

1. Dr. Bobby Ezhuthachan
2. Mr. Subrat Kumar Das
3. Mr. Sanjoy Datta
4. Mr. Santosh Kumar Singh
5. Mr. Akhilesh
6. Mr. M.C. Kumar
7. Mr. Shailesh G. Kulkarni
8. Dr. Prabhu R.
9. Dr. Pooja Srivastava
10. Dr. Sayantani Bhattacharyya
11. Tapomay Guha Sarkar
12. Dr. Efgnwande Osoba

Visiting Scientist

1. Dr. Andreas Nyffeler (Physics)
2. Dr. Sushan Konar (Physics)
3. Prof. Satya Deo (Maths)
4. Dr. Kirtiman Ghosh (RECAPP)
5. Ms. Arti Girdhar (Principal Investigator of DST)
6. Dr. Suvrat Raju (Ramanujan Fellow)
7. Prof. M.K. Parida (Neutrino)

Research Scholar

Mathematics

1. Mr. Vijay Kumar Sohani
2. Mr. Karam Deo Shankhadhar
3. Mr. Amrutiya Sanjaykumar Hansraj
4. Mr. Chintamani Mohan Namdev
5. Mr. Jaban Meher
6. Mr. Moriya Bhavinkumar Kishorsinh
7. Mr. Jay Gopalbhai Mehta
8. Mr. Pradip Kumar
9. Mr. Akhilesh P.
10. Mr. G. Kasi Viswanadham
11. Mr. Pradeep Kumar Rai
12. Ms. Eshita Mazumdar
13. Mr. Divyang G. Bhimani
14. Mr. Senthil Kumar K.
15. Mr. Ramesh Manna
16. Ms.Sneh Bala Sinha

Physics

1. Mr. Girish P. Kulkarni
2. Ms. Ipsita Mandal
3. Mr. Viveka Nand Singh
4. Mr. Rajarshi Tiwari
5. Mr. Shailesh Lal

6. Mr. Dhiraj Kumar Hazra
7. Mr. Satyanarayan Mukhopadhyay
8. Mr. Sanjoy Biswas
9. Mr. Joydeep Chakraborty
10. Ms. Desai Nishita D.
11. Mr. Ram Lal Awasthi
12. Mr. Manoj Kumar Mandal
13. Mr. Atri Bhattacharya
14. Mr. Saurabh Niyogi
15. Mr. Arunabha Saha
16. Mr. Ujjal Kumar Dey
17. Mr. Saurabh Pradhan
18. Mr. Vikas Chauhan
19. Mr. Sourav Mitra
20. Mr. Sabyasachi Tarat
21. Mr. Mohana Rao Barri
22. Mr. Nyayabanta Swain
23. Mr. Abhishek Chowdhury
24. Mr. Swapnamay Mondal
25. Ms. Akansha Singh
26. Ms. Shrobona Bagchi
27. Mr. Raghunath Ghara
28. Mr. Dharmadas Jash
29. Mr. Mehedi Masud
30. Mr. Avijit Misra

31. Mr. Narayan Rana
32. Mr. Maguni Mahakhud
33. Ms. Avinanda Chaudhuri
34. Mr. Utkarsh Mishra
35. Ms. Ushoshi Maitra
36. Mr. Udit Narayan Chawdhury
37. Mr. Roji Pius
38. Mr. Taushif Ahmed
39. Mr. Aritra Gupta
40. Mr. Abhishek Joshi
41. Mr. Shankha Banerjee

Academic Report - Mathematics

Sukumar Das Adhikari

Research Summary:

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

Publications:

1. Sukumar Das Adhikari, A. A. Ambily and B. Sury, *Zero-sum problems with subgroup weights,* Proc. Indian Acad. Sci. (Math. Sci.) 120, No. 3, 259–266 (2010).

2. Sukumar Das Adhikari and Mohan N. Chintamani, *Number of weighted subsequence sums with weights in* $\{1, -1\}$ Integers, to appear.

Conference/Workshops Attended:

1. ICM 2010 satellite conference on Dynamical systems, The MS University of Baroda, Vadodara, September 2010.

2. ICM 2010 satellite conference on Analytic and Combinatorial Number Theory, The Institute of Mathematical Sciences (IMSc), Chennai, September 2010.

3. 98th Indian Science Congress, SRM University, Chennai, January, 2011.

4. 21st Annual conference of Jammu Mathematical Society and a National Seminar on "Analysis and its applications", February 25 – 27, 2011.

Visits to other Institutes:

1. Ramakrishna Mission Vivekananda University, Belur, in April 2010, January 2011, March 2011.

2. Center for Combinatorics, Nankai University, Tianjin, in October, 2010.

3. National Institute of Science Education and Research, (NISER) Bhubaneswar, on November 26, 2010.

4. IMSc, Chennai, in January 2011 and March 2011.

Invited Lectures/Seminars:

1. *Fractional parts of powers, Pisot-Vijayaraghavan numbers and dynamics*, ICM 2010 satellite conference on Dynamical systems, The MS University of Baroda, Vadodara, September 2010.

2. *Weighted sums in Finite abelian groups*, ICM 2010 satellite conference on Analytic and Combinatorial Number Theory, The Institute of Mathematical Sciences (IMSc), Chennai, September 2010.

3. *Early Ramsey-type theorems in Combinatorial Number Theory*, Institute Colloquium Lecture, School of Mathematical Sciences, National Institute of Science Education and Research, (NISER), Bhubaneswar, November 2010.

4. *Partition function congruences*, Workshop on "Ramanujan's Mathematics", NASI, Allahabad, December, 2011.

5. *Cauchy-Davenport theorem: some generalizations and applications*, Symposium on "Number Theory, Combinatorics and Special Functions' in 98th Indian Science Congress, SRM University, Chennai, January, 2011.

6. *EGZ theorem: Various proofs*, 98th Indian Science Congress, SRM University, Chennai, January, 2011.

7. *Some classical results in additive combinatorics and some recent developments'*, The 21st Annual conference of Jammu Mathematical Society and a National Seminar on "Analysis and its applications", Jammu Mathematical Society, University of Jammu, February, 2011.

8. *Classical Ramsey type theorems: Interrelations and applications*, Colloquium in special year in number theory at IMSc, The Institute of Mathematical Sciences, Chennai, March, 2011.

Other Activities:

1. Gave a series of lectures in Combinatorics in the MTTS programme held at HRI in June 2010.

2. Working as a member of the editorial board of the periodical 'Mathematics Newsletter' published by Ramanujan Mathematical Society.

3. Gave a course of Topology for the first year Ph. D. students at HRI in the first semester of 2010-11.

4. Gave a short course on Number Theory for the final year M. Sc. students at Ramakrishna Mission Vivekananda University, Belur.

5. Currently Dean (academic), Harish-Chandra Research Institute.

Punita Batra

Research Summary:

Trying to find the irreducible integrable modules for an infinite dimensional Lie algebra, which is the fixed point set of several commuting finite order automorphisms of a finite dimensional simple Lie algebra over complex numbers attached with a subspace of the centre and derivations.

Publications:

1. Punita Batra,Volodymyr Mazorchuk, *Blocks and Modules for Whittaker pairs*, Journal of Pure and Applied Algebra, **215**(2011),1552-1568.

Conference/Workshops Attended:

1. *ICM satellite Conference Algebraic and Combinatorial approaches to Representation Theory,* IISc, Bangalore, August 12-14, 2010.

2. *ICM (International Congress of Mathematicians),* Hyderabad, August 19-21, 2010.

3. *International Conference on Non-Commutative Rings and Combinatorial Representation Theory,* Pondicherry University, Pondicherry, September 2-3, 2010.

Visits to other Institutes:

1. IISc, Bangalore, August 12-14, 2010.

2. Pondicherry University, September 2-3. 2010.

Invited Lectures/Seminars:

1. Gave an invited talk *"Highest weight modules over pre-exp-polynomial Lie algebras"* in the International Conference on Non-Commutative Rings and Combinatorial Representation Theory, Pondicherry University, September 2, 2010.

Other Activities:

1. Gave six lectures on "Field Theory and Galois Theory" in Summer Programme in Mathematics(SPIM) at HRI in June, 2010.

2. Gave two lectures in the Rajbhasha scientific workshop at HRI in July, 2010.

3. Organised an ICM satellite Conference "Algebraic and Combinatorial approaches to Representation Theory" at IISc, Bangalore during August 12-14, 2010.

4. 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

Research Summary:

In a joint work with S. Kanemitsu and X.-H. Wang, we locate a class of fundamental identities for the gamma function and trignometric functions in the chart of functional equations of the zeta function.
In another joint work with S. Kanemitsu and T. Kuzumaki we develop the theory of Barnes multiple zeta-function from a slightly different point of view using the Norlund generalized Bernoulli polynomials and apply it to the integral of the multiple gamma function.
In another joint work with Jorge Jimenez Urroz and Francesco Pappalardi, we studied pairs of integers which are mutually squares. Previously results always dealt with square free integers and this assumption allowed a series of technical complications. We remove this condition and provide a asymptotic formula.
In a joint work with Jay Mehta, we proposed authenticated key agreement and key confirmation Protocols using cryptographic bilinear maps. Work is in progress to propose 'blind digital signature' Protocols.

Publications:

1. Kalyan chakraborty, *On the Chowla-Selberg integral formula for non-holomorphic Eisenstein series* Integral Transformations and Special Functions, Vol.21, No.12, 2010, 917–923

2. K. Chakraborty, S. Kanemitsu and X. -H. Wang, *The modular relation and the digamma function* Kyushu J. Math. 65, 2011, 39–53.

Preprints:

1. K. Chakraborty, S. Kanemitsu and H. Tsukada, *Arithmetical Fourier series and the modular relation* (Pre-print)

2. K. Chakraborty, S. Kanemitsu and T. Kuzumaki, *On the Barnes multiple zeta and gamma function* (Pre-print)

3. Kalyan Chakraborty, Jorge Jiménez Urroz and Francesco Pappalardi, *Pairs of integers which are mutually squares* (Pre-print)

4. Kalyan chakraborty and Jay Mehta, *Authenticated key agreement and key confirmation Protocols using cryptographic bilinear maps* (Pre-print)

Conference/Workshops Attended:

1. *Two Day Conference in Mathematics*, Alwar, December 2010.
2. *CIMPA School of Number Theory in Cryptography and Its Applications*, Nepal, July, 2010.
3. *International Conference in Number Theory*, China, March 2011.
4. *Conference to honour Prof. R. Balasubramanian on his 60th Birthday*, Chennai, March 2011,

Visits to other Institutes:

1. Kathmandu niversity, Kathmandu, Nepal, July 2010,
2. Weinan Teachers University, Weinan, China, March 2011,
3. Institute of Mathematical Sciences, Chennai, India, March 2011,
4. NIIT, Alwar, India, December 2010.

Invited Lectures/Seminars:

1. *CIMPA School Of Number Theory in Cryptography and Its Applications*, Kathmandu University, Dulikhel, July 19th to July 31st, 2010.
2. *Introduction to Basic Cryptography*, International Conference in Number Theory, Weinan Teachers College, Weinan, China, March 2011.
3. *On the ABC Conjecture*, National Seminar in Mathematics and Applications, NIIT, Alwar, December 2010.

Other Activities:

1. Local Co-Ordinator of the various NBHM Tests, 2009–2010.
2. Refereed a Thesis for Doctorate degree, University of Burdwan, Burdwan.

Chandan Singh Dalawat

Research Summary:

Let p be a prime number and let F be any field. Call a degree-p extension E of F *solvable* if it is separable and if the group $\mathrm{Gal}(\tilde{E}|F)$ of F-automorphisms of the galoisian closure $\tilde{E}|F$ of $E|F$ is solvable. It turns out that any such extension becomes cyclic when translated to the maximal abelian extension K of F of exponent dividing $p-1$, and hence the compositum C of all degree-p solvable extensions of F is contained in the maximal elementary abelian p-extension M of K. We have completely determined C in terms of the conjugation action of $G = \mathrm{Gal}(K|F)$ on the group $H = \mathrm{Gal}(M|K)$. For example, when F is a local field with finite residue field k of characteristic l, then $C = M$ if $p = l$, and $C = K'(\sqrt[p]{K'^{\times}})$, with $K' = F(\sqrt[p]{1})$, if $p \neq l$.

In the case of a local field F of residual characteristic p, we carry out a detailed study of the filtered G-module $K^{\times}/K^{\times p}$ in characteristic 0 and $K/\wp(K)$ in characteristic p. These G-modules are closely related to the G-module H. This allows us to give an elementary and conceptual proof of Serre's mass formula in prime degree (arXiv:1005.2016, to appear in the *Monatshefte*).

We have written an accessible account of reciprocity laws, illustrated with numerous striking examples such as the quadratic or the cylotomic reciprocity law or the modularity of rational elliptic curves (to appear in a commemorative volume dedicated to Mysore University).

Publications:

1. Chandan Singh Dalawat, *Further remarks on local discriminants*, Journal of the Ramanujan Mathematical Society **25** 4, 391–417 (2010). Cf. arXiv:0909.2541.

2. Chandan Singh Dalawat, *Primary units in cyclotomic fields*, to appear in the Annales des sciences mathématiques du Québec. Cf. arXiv:0911.2566.

3. Chandan Singh Dalawat, *Final remarks on local discriminants*, Journal of the Ramanujan Mathematical Society **25** 4, 419–432 (2010). Cf. arXiv:0912.2829.

4. Chandan Singh Dalawat, *Serre's "formule de masse" in prime degree*,

published online 30/12/2010 on Springerlink, to appear in Monatshefte für Mathematik. Cf. arXiv:1005.2016.

5. Chandan Singh Dalawat, *Splitting primes*, to apper in Math Unlimited: Essays in Mathematics, Science Publishers, Delhi. Cf. arXiv:1007.4426.

Conference/Workshops Attended:

1. *Galois representations in arithmetic and geometry*, Goa, 10–13 August 2010.

2. *Automorphic forms and number theory*, Goa, 14–17 August 2010.

3. *International congress of mathematicians*, Hyderabad, 19–27 August 2010.

Invited Lectures/Seminars:

1. *Splitting primes*, Institute Colloquium, IISER Mohali, 22 September 2010 ; LNMIIT Jaipur, 16 November 2010.

2. *Serre's mass formula in prime degree*, Institute Seminar, IISER Mohali, 23 September 2010 ; Mathematics Seminar, IISc Bangalore, 19 January 2011.

Other Activities:

Supervised an undergraduate student from Poona. Organised the satellite conference on *Galois representations in arithmetic and geometry* in Goa, 10–13 August 2010.

Rukmini Dey

Research Summary:

I finished one paper on the geometric quantization of non-abelian vortices with Dr. Samir Paul, S.N.Bose Center. I also started work on coadjoint orbit quantization of certain integrable systems with Professor Dileep Jatkar and Dr. Samir Paul. I am also finishing a paper on Multitransonicity of blackhole accretion with Dr. Tapas Das and Dr. Sankhasubhra Nag –there is a beautiful bifurcation theory there which we are trying to understand and explain in terms of Thom Catastrophe.
With my student, Pradip Kumar Misra, we are making headway in trying to interpolate between two real analytic curves by a minimal surface. The main problem here is to figure out how far apart the curves are so that there is an interpolating minimal surface.
In addition I am guiding Pradip and Saikat Chatterjee in developing connections on path spaces using rigourous mathematics.
Finally I am trying to set up a rigourous mathematical framework in which I can explain my geometric quantization of various moduli spaces using the modifications of the Quillen bundle, a programme which I started with the help of my thesis guide, Professor Leon Takhtajan in USA and developed subsequently in India.

Publications:

1. Rukmini Dey, Samir Paul, *Quillen bundle and Geometric Quantization of non-abelian vortices,* Proc.Indian Acad. Sci (Math. Sci.) **Vol 121, No. 1**, pg. 1-9, (2011)

Preprints:

1. Shilpi Agarwal, Tapas Das, Rukmini Dey, Shankhasubhra Nag, *Mutitransonicity of blackhole accretion and bifurcation theory* (in preparation)

2. Rukmini Dey, *Geometric prequantization of various moduli spaces* (in preparation)

3. Rukmini Dey and Pradip Kumar Misra *Interpolating minimal surface between two real analytic curves and bifurcation theory* (in preparation)

Conference/Workshops Attended:

1. Bhuvaneswar Symposium on non-commutative geometry , mathematical physics and number theory, Institute of Mathematics and Application, India, Jan 12-16, 2011.

2. . Conference: 2nd Workshop on Combinatorics of Moduli spaces, cluster algebras and symplectic invariants, May 24-28th, 2010, Stekhlov Math Institute and Independent University of Moscow, Moscow.

3. . Conference: Interntaional Congress of Mathematicians, Aug 19-27th, 2010, Hyderabad.

4. . 2nd Workshop on Combinatorics of Moduli spaces, cluster algebras and symplectic invariants, Steklov Math Institute and Independent University of Moscow, Moscow, Russia, May 24-28th, 2010.

5. . Hyderbabad, International Congress of Mathematicians, Aug 19-27th, 2010, Hyderabad, Aug 19-27th, 2010.

Visits to other Institutes:

1. S.N. Bose Center of Basic Sciences, Kolkata, India, May, 2010,

2. R.R.I. and I.I.Sc, Bangalore, India, June, 2010.

3. DAMTP, University of Cambridge and University of Oxford, England, India, May, 2010

4. Stekhlov Math Institute and Independent University of Moscow, Russia, India, May 2010.

5. Institute of mathematics and its applications, Bhuvaneswar, India, Jan 12-16, 2011

Invited Lectures/Seminars:

1. *Quillen bundle and geometric prequantization of various moduli spaces*, , Bhuvaneswar symposium on Non-commutative Geometry and Mathematical Physics and Number theory, Bhuvaneswar, Jan 2011

2. *same talk*, , Stekhlov Institute and Independent University, Moscow, May 2010.

3. *same talk* , DAMTP, University of Cambridge, England, May 2010
   same talk , R.R.I., Bangalore, India, June 2010

Other Activities:

1. I helped write up a joint 5-year project with Dr. Ratnakumar, on the Geometry and Analysis of Quantization, as a part of the XII Plan.

2. I do social work, helping village children with their studies, teaching them songs and taking part in organizing plays.

3. I also run a wall magazine to foster creative writing amongst children of all ages from all sections of society and now help in running wall magazines for adults.

D. Surya Ramana

Research Summary:

Together with O. Ramaré we obtained an optimal upper bound for $t(k)$, 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 a preprint in preparation we show that $t(k) \ll K \log\log K$ answering a question of A. Sárközy and improving on results of N. Hegyvari and F. Hennecart who had obtained $t(K) \ll K^3$.
In the preprint *Averaged Decay Rate of the Fourier Transforms of Piecewise Affine Linear Functions on* $\mathbf{R}^n$ we obtain optimal decay rates of the fourier transform of the functions in title, averaged over $\mathbf{R}^n$. The method uses the Stokes formula together with an approriate decomposition of the support of the function. This result finds application in a work of O. Ramaré on long tuples with few prime factors. The preprint has been reproduced as a section of the paper *On long κ-tuples with few prime factors* by O. Ramaré, which is to appear in the Proceedings of the London Mathematical Society.

Preprints:

1. D.S. Ramana, *Averaged Decay Rate of the Fourier Transforms of Piecewise Affine Linear Functions on* $\mathbf{R}^n$.

2. D.S. Ramana and O. Ramaré, *Additive Energy of Dense Sets of Primes and Monochromatic Representation*, (in preparation).

Conference/Workshops Attended:

1. *I.C.M. Sattelite Conference*, Institute of Mathematical Sciences, August-September, 2011.

Other Activities:

1. Guided two visiting students in the summer in the summer of 2010.

2. Currently Ph.D. adviser to two students of the HRI graduate programme.

3. Taught one course each in the semester August-December 2010 and January-May, 2011 in the HRI graduate programme.

4. Served on the Local Works Committee of HRI for 2010-2011. Also, assisted the Director, HRI in supervising ongoing building projects.

Ramakrishnan B.

Research Summary:

1. Special values of certain Dirichlet L-functions: In our earlier paper (with S. Gun) [Ramanujan J. **15** (2008), 275–280], we gave expressions for the special values of certain Dirichlet L-function in terms of finite sums involving Jacobi symbols. In this note, we extend our earlier results by giving similar expressions for two more special values of Dirichlet L-functions, namely $L(-1, \chi_m)$ and $L(-2, \chi_{-m'})$, where m, m' are square-free integers with $m \equiv 1 \pmod 8$ and $m' \equiv 3 \pmod 8$ and χ_D is the Kronecker symbol $\left(\frac{D}{\cdot}\right)$. As a consequence, using the identities of H. Cohen, we also express the finite sums with Jacobi symbols in terms of sums involving divisor functions. Finally, we observe that the proof of Theorem 1.2 in [Ramanujan J. **15** (2008), 275–280] is a direct consequence of our result (joint with S. Gun and M. Manickam) [Math. Ann. **347**(2010), 899-916, Eq(24)].

2. Restriction map for Jacobi forms (joint with Karam Deo Shankhadhar): In two papers [Abh. Math. Sem. Univ. Hamburg **69**(1999); J. reine angew. Math. **559**(2003)], T. Arakawa and S. Böcherer studied the kernel of the restriction map on the space of Jacobi forms. If ϕ is a Jacobi form of weight k, index 1, level N, they studied the kernel of the restriction map given by $\phi(\tau, z) \mapsto \phi(\tau, 0)$. For a Jacobi form ϕ in the kernel of the above map, the authors associate a modular form φ of weight $k-1$ and level N. Further, using the differential operator D_2, they also associate a cusp form of weight $k+2$ and level N, for a given Jacobi form in the kernel. In this work, we extend this result to Jacobi forms of half-integral weight. Further work is in progress to get similar results in the case of Jacobi forms of index greater than 1.

3. Non-Vanishing of L-Functions (joint with Karam Deo Shankhadhar). Let $\{f_1, \ldots, f_r\}$ be a basis of Hecke eigenforms of S_k, normalized by the Petersson scalar product. In 1997, W. Kohnen showed that $\sum_{j=1}^{r} \Lambda(s, f_j)/w(f_j)$ does not vanish in $\operatorname{Re} s \in (\frac{k-1}{2}, \frac{k}{2} - \varepsilon) \cup (\frac{k}{2} + \varepsilon, \frac{k+1}{2})$, if k is large in terms of $\operatorname{Im} s$ and ε. Here $w(f_j)$ is a number of absolute value 1 and Λ is the completed L-function. In this work, we obtain similar results in the case of Hecke eigenforms of half-integral weight.

4. Theory of newforms of half-integral weight (with M. Manickam and Jaban Meher). Work is in progress to develop the theory of newforms in the Kohnen plus space on $\Gamma_0(8N)$ and $\Gamma_0(16N)$, where N is an odd square-free integer.

Publications:

1. S. Gun, M. Manickam and B. Ramakrishnan, *A canonical subspace of modular forms of half-integral weight*, Math. Ann. **347**(2010), 899–916.

2. Jaban Meher and B. Ramakrishnan, *A note on Pseudo-Eigenvalues of the Atkin-Lehner W-Operators*, Proceedings of 20th Annual Conf. of Jammu Math. Soc. 2010, pp. 1–7 (2011).

Preprints:

1. B. Ramakrishnan, *A Note on Special Values of Certain Dirichlet L-functions*.

2. B. Ramakrishnan and Karam Deo Shankhadhar, *Non-vanishing of L-functions associated to cusp forms of half-integral weight inside the critical strip*.

Conference/Workshops Attended:

1. *Modular Forms, ICM satellite workshop*, Mamallapuram, India, August, 2010.

2. *International Congress of Mathematicians*, Hyderabad, India, August 2010.

3. *ICM Satellite Conference*, IMSc, Chennai, India, September, 2010.

4. *21st Annual Conference of the Jammu Mathematical Society*, University of Jammu, Jammu, India, February, 2011.

Visits to other Institutes:

1. Ramakrishna Mission Vivekananda College, Chennai, India, June 2010.

2. Department of Mathematics, Vivekananda University, Belur, India, February, 2011.

3. Institute of Mathematical Sciences, Chennai, India, March 2011.

Invited Lectures/Seminars:

1. *Jacobi Forms*, ICM Satellite workshop, Vivekananda College, Mamallapuram, India, August 2010.

2. *Special values of certain Dirichlet L-functions*, ICM Satellite conference, IMSc, Chennai, September 2010.

3. *Elementary Number Theory*, Mini MTTS programme, Bhanasthali University, Bhanasthali, December 2010.

4. *Correspondences between Modular forms and Jacobi forms*, IMSc colloquium, The Institute of Mathematical Sciences, Chennai, March 2011.

5. *Introduction to Modular Forms*, Masters course, Vivekananda University, Belur, February 2011.

6. *Certain identities for the Ramanujan Tau function*, Jammu Mathematical Society Annual Conference, University of Jammu, Jammu, India, February, 2011.

Other Activities:

1. Supervising two research scholars at HRI for their PhD.

2. Chaired a short communications session on Number Theory at the International Congress of Mathematicians, Hyderabad, August, 2010.

3. Analysis II course (second semester) at HRI, January-May, 2011.

4. Advisory committee meeting of the UGC-SAP DRS-1 programme (Mathematics), Lucknow University, March 2011.

Ratnakumar Peetta Kandy

Research Summary:

In the last one year, I have been working, jointly with my collaborators on three problems. The first one concerns the well posedness problem for the non linear Schroedinger equation associated to the special Hermite operator. In dimension two, this refers to the magnetic Schrödinger operator corresponding to constant magnetic field. This is a joint work with my Ph. D. Student Vijay Sohani. We have been successful in proving well posedness for a large class of nonlinearities, including power type non linearities, using the main Strichartz type estimate that I have obtained for special Hermite operator, appeared recently in Journal of Fourier analysis and applications. The non linear analysis required more Strichartz' type estimates including retarded ones, which we were able to establish.

A related work concerns the Schroedinger propagator for the Dunkl Laplacian, Jointly with Salem Ben Said and A.K.Nandakumaran. Dunkl Laplacian is the sum of squares of Dunkl translation operators. The Dunkl translation operator is a differential - difference operator associated to a given root system $\mathcal{R}$ and a multiplicity function k. We have proved the Strichartz estimates for the Dunkl laplacian. Our work relies on the spectral theory of the Dunkl operators recently developed by S. Ben Said, T. Kobayashi and B. Oersted. This work is completed and sent for publication.

The third one is an ongoing work with E.K. Narayanan on uncertainty principle. We have obtained a qualitative uncertainty principle on two step nilpotent Lie Groups. This extends our previous work in this direction on the Heisenberg group, to more general two step nilpotent Liegroups. More over, in the case of the so called MW groups, our result also improves the previously obtained result, in particular the one on the Heisenberg group.

Publications:

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

Preprints:

1. S. Ben Said, A.K. Nandakumaran and P.K. Ratnakumar, *Schrödinger propagator and the Dunkl Laplacian,* (submitted for publication)
2. P.K. Ratnakumar and Vijay Kumar Sohani, *Non-linear Schrödinger equation for the special Hermite operator*, (in preparation)
3. E.K.Narayanan and P.K. Ratnakumar, *A qualitative uncertainty principle on two step nilpotent Lie groups* (in preparation)

Conference/Workshops Attended:

1. *International Congress of Mathematicians*, India, August 2010.
2. *Satellite Conference on Harmonic Analysis*, India, Aug 29-Sept 2, 2010.
3. *School on Analysis, Algebra and Topology*, Keral School of Mathematics, India, 29th Dec 27, 2010 -7th Jan 201.

Visits to other Institutes:

1. Dept. of Mathematics, Brock University, Toronto, Canada, April 2010.
2. Keral School of Mathematics, Calicut, India, 29th Dec. 2010 to 7th Jan 2011.
3. IISER Trivandrum, India, 10-20th January 2010.

Invited Lectures/Seminars:

1. *Schroedinger propagator for differential operators with discrete spectrum*, Satellite Conference on Harmonic Analysis, NISER, Bhubaneswar, Aug 29 - Sept 2, 2010.
2. *Lectures on Fourier Analysis*, School on Analysis, Algebra and Topology, Kerala School of Mathematics, Calicut, 29th Dec 2010- 4th Jan 2011.

Other Activities:

1. Served in Sports and entertainment committee.
2. Served in the Pantry and Guest house committee.

R. Thangadurai

Research Summary:

An asymptotic formula with better error term was derived for the number representations of an integer which can be written as a sum of square of a prime and a square free integer. To do this, we had to invoke a weighted version of Bombieri - Vinogradov Theroem on the primes in arithmetic progression and the number of integer solutions of $n = ax^2 + by^2$ and other analytic estimations. Using elementary esitmates, an upper bound was found for the least prime in arithmetic progression $p \equiv 1 \pmod{n}$. Using Davenport's theorem on character sum estimates, it was proved that for any given natural number $N \geq 2$, there are N consecutive integers which are square (respectively, non-square) modulo p for all prime $p \geq f(N)$ where $f(N)$ is an explicit function of N. A systematic study on the number of positive integer solutions of the Diophantine equation $x^2 + dy^2 = n$ was done for a square free integer $d \neq 1$.

Publications:

1. R. Balasubramanian and R. Thangadurai, *Collected works of S. Sivasankaranarayana Pillai*, Collected works series, Ramanujan Mathematical Society, **1**, (2010).

2. M. Ram Murty and R. Thangadurai, *The class number of* $\mathbf{Q}((-p)^{1/2})$ *and digits of* $1/p$, Proc. Amer. Math. Soc., **139**, 1277-1289, (2011)

Preprints:

1. R. Thangadurai and A. Vatwani, *The least prime p congruent to* 1 *modulo* n, To appear in: American Mathematical Monthly.

2. M. Ram Murty and R. Thangadurai, *On a paper of S. S. Pillai,* To appear in: Proc. Indian Acad. Sci. (Ser. A).

3. J. Tanti and R. Thangadurai, *Distribution of residues and primitive roots*, Preprint.

4. S. Subburam and R. Thangadurai, *On positive integral solutions of some norm elements in Quadratic fields*, Preprint.

Conference/Workshops Attended:

1. *Satellite conference to ICM 2010 on "Analytical and Combinatorial Number theory*, India, September 2010.

Visits to other Institutes:

1. Institute of Mathematical Sciences, Chennai, India, August, 2010 and December, 2010 to April, 2011.

2. Indian Institute of Science Education Research, Kolkata, India, December, 2010.

Invited Lectures/Seminars:

1. *The least prime in certain arithmetical progression*, Number theory Seminar, IISER, Kolkata, December, 2010.

2. *An equi-distribution theorem*, Satellite conference to ICM 2010, IMSc, Chennai, September, 2010.

Other Activities:

1. Local co-ordinator for MTTS Programme held HRI during 24th May to 19th June, 2010.

2. Co-ordinator for SPIM 2010 held at HRI during 21st June to 10th July, 2010.

3. Taught 'Analysis - I' for the first year graduate students during August-December, 2010.

4. Co-organizer for the satellite conference to ICM 2010 on 'Analytical and Combinatorial Number Theory' held at IMSc, Chennai during 29th August to 4th September, 2010.

5. Member of Library committee and the Convener of the Mathematics Graduate Committee at HRI.

Manoj Kumar

Research Summary:

(i) We have completed the following works, which we have been doing through the year 2009 - 2010.

(ia) 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. We (jointly with Vivek Kumar Jain) have studied finite p-groups G, p an odd prime, whose all automorphisms are central. One can notice that such groups must be of nilpotency 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 have constructed counter examples to this conjecture. We have also constructed 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.

(ib) 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.

(ii) Let G be a finite p-group and $|G| = p^n$, where p is a prime and n is a non-negative integer. For $x \in G$, x^G denotes the conjugacy class of x in G. Let $Aut_c(G)$ denote the set of all class preserving automorphisms of G. Let $\{x_1, \cdots, x_d\}$ be any minimal generating set for G. Let $\alpha \in Aut_c(G)$. Since $\alpha(x_i) \in x_i^G$ for $1 \leq i \leq d$, there are at the most $|x_i^G|$ choices for the image of x_i under α. Thus it follows that

$$|Aut_c(G)| \leq \prod_{i=1}^{d} |x_i^G|. \tag{1}$$

We have been studying finite p-groups G which satisfy the following hypothesis:

Hypothesis. $|Aut_c(G)| = \prod_{i=1}^{d} |x_i^G|$ for every minimal generating set $\{x_1, x_2, \cdots, x_d\}$ of G.

We have observed that this study can be applied in the following setup: Let G be an arbitrary group such that $G/Z(G)$ is finite, where $Z(G)$ denotes the center of the group G. Then $\gamma_2(G)$, the commutator subgroup of G, is finite. This result is known as Shur's theorem. It has been recently proved that if $G/Z(G)$ is finitely generated and $\gamma_2(G)$ is finite, then $G/Z(G)$ is finite and $|G/Z(G)|$ can be bounded in terms of $|\gamma_2(G)|$ and the cardinality of a minimal generating set of the given group G. More precisely, let $G/Z(G)$ is minimally generated by d elements, then $|G/Z(G)| \leq |\gamma_2(G)|^d$. A natural problem which arises here is the following:

Problem. Classify all finite groups G such that $G/Z(G)$ is minimally generated by $d(G)$ elements, $\gamma_2(G)$ is finite and $|G/Z(G)| = |\gamma_2(G)|^{d(G)}$.

We are in the process of applying our results on automorphisms of finite p-groups to solve this problem.

Publications:

1. I. B. S. Passi, Mahender Singh and Manoj K. Yadav, *Automorphisms of abelian group extensions,* J. Algebra **324**, 820-830, (2010).

Preprints:

1. Vivek Kumar Jain and Manoj K. Yadav, *On finite p-groups whose automorphisms are all central*, Accepted for publication in Israel J. Math.

2. V. Bardakov, A. Vesnin and Manoj K. Yadav, *Class preserving automorphisms of unitriangular groups,* Submitted for publication.

3. Manoj K. Yadav, *Automorphisms, central quotients and commutator subgroups of finite nilpotent groups,* In preparation.

Conference/Workshops Attended:

1. *25th Annual Conference of Ramanujan Mathematical Society*, India, May 2010.

2. *International Congress of Mathematicians (ICM)*, India, August 2010.

3. *International Conference on Buildings, Finite Geometries and Groups*, India, August 2010.

4. *International Workshop cum Conference on Groups, Actions, Computations (GAC2010)*, India, September 2010. (As a local organizer).

Visits to other Institutes:

1. IISER Mohali, India, March 2011.

2. IISER Pune, India March 2011.

Invited Lectures/Seminars:

1. *On subgroups generated by small elements in finite groups*, 25th Annual Conference of Ramanujan Mathematical Society, NIT Jalandhar, May 2010.

2. *On finite p-groups whose automorphisms are all central*, IISER Mohali, March 2011.

3. *Automorphisms of finite p-groups*, IISER Pune, March 2011.

4. *Central automorphisms of finite p-groups*, IISER Pune, March 2011.

Other Activities:

1. Organised an International Workshop cum Conference on Groups, Actions, Computations (GAC2010), Sept 01 - 12, 2010 at HRI. (Jointly with Siddhartha Sarkar (IISER, Bhopal) and Juergen Mueller (RWTH, Aachen, Germany)).

2. Gave six lectures in SPIM at HRI, June 2010.

3. Gave a month long course on group theory to MTTS student at Mysore, May 17 - June 12, 2010.

4. Gave two lectures in Rajbhasha programme, May 2010.

5. I was a member of various committees constituted in HRI, 2010 - 2011.

Gyan Prakash

Research Summary:

A celebrated result of Bourgain,Glibichuk and Konyagin gives a non-trivial upper bound for the Fourier transform of a multiplicative subgroup of $(\mathbf{Z}/p\mathbf{Z})^*$, where p is a prime number, under any non-trivial additive character of $\mathbf{Z}/p\mathbf{Z}$. In an ongoing work with my co-author Harald Helfgott, we realised that this result can be interpreted in a representation theoretic language. More generally we ask the following question:

Let $\delta > 0$ be a real number. Let U be a maximal unipotent subgroup of $\mathrm{SL}_n(\mathbf{Z}/p\mathbf{Z})$ and T_0 be a subgroup of torus group with $|T_0| \geq p^\delta$. Let B_0 be the semidirect product of U and T_0 and, χ be an irreducible representation of U and π be the induced representation of B_0 induced by χ, that is $\pi = \mathrm{Ind}_U^{B_0}\chi$. Then is it true that the trace of any element $u \in U$ is at most $\dim(\pi)p^{-\epsilon}$, where $\epsilon > 0$ depends only upon n and δ and in particular does not depend upon p or χ?

When $n = 2$, then the above question is equivalent to the result of Bourgain etc. mentioned above. The special case of the above question, when $n = 3$, corresponds to the Kloosterman sum with variable **restricted** to a small subgroup of $(\mathbf{Z}/p\mathbf{Z})^*$. We realise that the method of Bourgain etc. leads easily to a non-trivial upper bound for this sums. Recently we realise that this particular case of the question also follows directly from another paper of Bourgain. However the general question mentioned above seems to be open and may have interesting applications. We are presently working to obtain an answer of the general question mentioned above.

Publications:

1. Jean-Marc Deshouillers and Gyan Prakash, *Large zero-free subsets of* $\mathbf{Z}/p\mathbf{Z}$, Integers **11**, 399-420, (2011)

Visits to other Institutes:

1. The Institute of Mathematical Sciences, Chennai, India, March, 2011.

Satya Deo

Research Summary:

One area of my present research interest has been to work on topological methods in combinatorial mathematics in general. I have been concentrating mostly on my DST research project entitled "Topological Methods in Combinatorial Mathematics" jointly with S.D.Adhikari. We have in turns conducted research seminars on the works of Lovasz, Barani and others using the Borsuk-Ulam Theorem of algebraic topology in an essential way.

During this academic year 2010-11 also, 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 and we are still trying to settle this.

Preprints:

1. Satya Deo and V.V.Awasthi, *Homology and Dimension- further pathological examples,* submitted
2. Satya Deo, *Cohomological dimension and finitistic spaces*, (in preparation)

Conference/Workshops Attended:

1. *76th Annual Conference of the Indian Mathematical Society*, NIT, Surat (Gujarat) Dec 27-30, 2010.
2. *98th Annual Session of the Indian Science Congress Association, SRM University, Chennai, Jan 3-7,2011*

Visits to other Institutes:

1. Department of Mathematics, Aligarh Muslim University, Aligarh, March 14-15, 2011.
2. Mathenmatics Department, University of Delhi, Delhi, South Campus
3. Mathematics Department, University of Delhi, Delhi
4. Department of Mathematics, R.D.University, Jabalpur,

Invited Lectures/Seminars:

1. *Manifolds and Homology*, AMU DSA Lecture, Aligarh Muslim University, Aligarh.
2. *Birth and Youth of Algebraic Topology*, DSA programme in Mathematics, Department of Mathematics, R.D.University, Jabalpur,

Academic recognition/Awards:

- Elected Academic Secretary, Indian Mathematical Society for the years 2011-2013.

Other Activities:

1. Taught a course on Topology-II at HRI during Jan-May 2011.
2. As the Academic Secretary, I planned and organized the complete academic programme of the 76th annual conference of the Indian Mathematical Society held at the NIT, Surat (Gujarat), Dec 27-30,2010.

Sanjaykumar Hansraj Amrutiya

Research Summary:

The notion of parabolic vector bundles over a compact Riemann surface was introduced by C. S. Seshadri. Let X be a compact Riemann surface with signature S. By Riemann existence theorem, there exists a finite ramified Galois covering $p : Y \longrightarrow X$ with the Galois group G such that the set of branched points is $\mathrm{Supp}(S)$ and the ramification index over a point x is $S(x)$ for every point $x \in \mathrm{Supp}(S)$. It is known that the category of G-equivarient holomorphic vector bundles over Y is equivalent to the category of parabolic vector bundles over X with the parabolic structure over $\mathrm{Supp}(S)$ whose all the weights are integral multiple of $1/S(x)$, for every point $x \in \mathrm{Supp}(S)$. I have been working on the problem related to parabolic dianalytic vector bundles over a compact connected non-orientable Klein surface.

Publications:

1. Sanjay Amrutiya and Indranil Biswas, *On the F–fundamental group scheme,* Bull. Sci. Math. **134**, 461-474, (2010)

Conference/Workshops Attended:

1. *Bundles on Projective Varieties*, TIFR (India), 03-14 May, 2010.
2. *Complex Geometry, Group actions and Moduli spaces*, University of Hyderabad, Hyderabad (India), 13-16 August, 2010.
3. *International Congress of Mathematicians*, Hyderabad (India), 19-27 August, 2010.

Mohan Namdev Chintamani

Research Summary:

Let G be a finite abelian group of order n and A be a (finite) non-empty subset of integers. A sequence $S : x_1, x_2, \cdots, x_r$ of elements of G is said to be an A-weighted zero-sum sequence if for some $a_i \in A$, we have $\sum_{i=1}^{r} a_i x_i = 0$.
In particular, when $A = \{1, -1\}$, we obtained a lower bound on the number of A-weighted zero-sum subsequences of a sequence S of elements of G which does not have 0 as an A-weighted n-sum. This is a weighted version of a result of Bollobás and Leader. As a corollary, one obtains a result of Adhikari, Chen, Friedlander, Konyagin and Pappalardi.

When $G \cong \mathbb{Z}/n\mathbb{Z}$ and the weight set $A = \{a^2 : a \in (\mathbb{Z}/n\mathbb{Z})^*\}$, extending some results of Adhikari, David and Urroz, we obtained an upper bound on the weighted Davenport constant $D_A(G)$ and on the weighted EGZ constant $E_A(G)$.

Publications:

1. M. N. Chintamani, B. K. Moriya and P. Paul, *The Number of Weighted n-Sums*, Int. J. Mod. Math. 5, no. 2, 215–222 (2010)

Preprints:

1. S. D. Adhikari and M. N. Chintamani, *Number Of Weighted Subsequence Sums With Weights In {1, -1}*, Submitted.

2. M. N. Chintamani and B. K. Moriya, *Generalizations of Some Zero Sum Theorems*, Submitted.

Conference/Workshops Attended:

1. *International Congress of Mathematicians*, Hyderabad, India, Aug 2011.

2. *International Conference on Analytic and Combinatorial Number Theory (a satellite conference to ICM 2010)*, 29th Aug–3rd Sep 2010.

3. *Special Year in Number Theory* at IMSc, Chennai, attended a part of, between Nov 27, 2010 – Jan 10, 2011.

Jaban Meher

Research Summary:

In a joint work with M. Manickam and B. Ramakrishnan, we establish the theory of newforms for $S^+_{k+1/2}(8N)$, the Kohnen plus space of cusp forms of weight $k+1/2$ for the group $\Gamma_0(8N)$, where N is an odd square free positive integer.Though the theory has been established by M. Ueda and S. Yamana, our method of proof is different. Moreover, we show that the space of new forms in $S^+_{k+1/2}(8N)$ is isomorphic to the space of newforms in $S^+_{k+1/2}(4N)$, where the isomorphism is provided by the Hecke operator $U(4)$. We also obtain Waldspurger theorem for newforms in the Kohnen plus space $S^{+,new}_{k+1/2}(8N)$. The work is in progress.

Publications:

1. W. Kohnen and J. Meher , *Some remarks on the q-exponents of generalized modular functions,* The Ramanujan Journal, **15, no.1**, 115-119, (2011).

2. J. Meher and B. Ramakrishnan, *A note on Pseudo-Eigenvalues of the Atkin-Lehner W-Operators,* Proceedings of 20th Annual Conf. of Jammu Math. Soc. 2010, 1-7, (2011).

Preprints:

1. M. Manickam, J. Meher and B. Ramakrishnan, *On the theory of newforms of half integral weight for $\Gamma_0(8N)$,* (in preparation).

Conference/Workshops Attended:

1. *Besse Summer School on Quasimodular forms*, Besse et Saint-Anastaise, Clermont Ferrand, France, 20-26 June, 2010.

2. *ICM Satellite Conference on Modular forms*, Mahabalipuram, 1-9 August, 2010.

3. *International Congress of Mathematicians*, Hyderabad, 19-27 August, 2010.

4. *ICM Satellite Conference on Analytic and Combinatorial Number Theory*, IMSc, Chennai, 29 August-3 September, 2010.

5. *IISER-Kolkata Winter School on Number Theory (Waring's Problem)*, IISER Kolkata, 13-17 December, 2010.

6. *School and Conference on Modular forms and Mock Modular forms and their Applications in Arithmetic, Geometry and Physics*, ICTP, Trieste, Italy, 28 February-18 March, 2011.

Visits to other Institutes:

1. The Institute of Mathematical Sciences, Chennai, August, 2010, January and March, 2011.

Invited Lectures/Seminars:

1. *On Generalized Modular functions*, ICM Satellite Conference on Modular forms, Mahabalipuram, August 2010.

Other Activities:

1. Tutor for IISER-Kolkata Winter School on Number Theory; December, 2010.

Bhavin K. Moriya

Research Summary:

I have been working on weighted zero sum problems. Let G is a finite cyclic group of order n, written additively, and A is a non-empty subset of $\{1, 2, \cdots, n-1\}$. The weighted EGZ constant $E_A(n)$ is the smallest positive integer t such that for every sequences $x_1, x_2, \cdots, x_t$ of elements of G, there exist indices $j_1, j_2, \cdots, j_n \in \mathbb{N},\ 1 \leq j_1 < j_2 < \cdots < j_n \leq t$ and $(a_1, a_2, \cdots, a_n) \in A^n$ with $\sum_{i=1}^{n} a_i x_{j_i} = 0$. In a joint work with M. N. Chintamani we have determined an upper bound on $E_A(n)$, where $A = \{x^2 : x \in (\mathbb{Z}/n\mathbb{Z})^*\}$. Also we have determined an exact value of $E_A(n)$, when $\gcd(n, 30) = 1$. This result extends result of S. D. Adhikari, C. David and J. Urroz.

Currently, I am reading algebraic number theory and zero sum problems.

Publications:

1. M. N. Chintamani, B. K. Moriya and P. Paul, *The number of weighted n-sums,* Int. J. Mod. Math. 5, no. 2, 215-222, (2010).

Preprints:

1. M. N. Chintamani and B. K. Moriya, *Generalizations of some zero sum theorems,* Preprint.

Conference/Workshops Attended:

1. Attended *some courses in a Number Theory Year* held at IMSc, Chennai during 23rd November 2010 to 18th March 2011.
2. *ICM Satellite Conference on Analytic and Combinatorial Number Theory* from 29 August - 3 September 2010 held at IMSc, Chennai.
3. *International Congress of Mathematicians* from 19-27 August 2010 held in Hyderabad, India.

Karam Deo Shankhadhar

Research Summary:

1 Non-Vanishing of L-Functions
Let $\{f_1, \ldots, f_r\}$ be a basis of Hecke eigenforms of $S_k(N, \psi)$, normalized by the Petersson scalar product. Then A. Raghuram (Ramanujan Math. Soc. Lecture Notes series 1, 2005) showed that $\sum_{j=1}^{r} \Lambda(s, f_j)/w(f_j)$, where $w(f_j)$ is a number of absolute value 1 and Λ is the completed L-function, does not vanish in $\mathrm{Re}\, s \in (\frac{k-1}{2}, \frac{k}{2} - \varepsilon) \cup (\frac{k}{2} + \varepsilon, \frac{k+1}{2})$, if k or N is large in terms of $\mathrm{Im}\, s$ and ε (for $N = 1$, this result was proved by W. Kohnen (JNT **67**, 1997)). We obtain similar results for L-functions of half-integral weight. This is a joint work with B. Ramakrishnan.

2 Restriction Map for Jacobi Forms
In two papers (Abh. Math. Sem. Univ. Hamburg **69**, 1999; J. reine angew. Math. **559**, 2003), T. Arakawa and S. Böcherer studied the kernel of the restriction map on the space of Jacobi forms. If ϕ is a Jacobi form of weight k, index 1, level N, they studied the kernel of the restriction map given by $\phi(\tau, z) \mapsto \phi(\tau, 0)$. For a Jacobi form ϕ in the kernel of the above map, the authors associate a modular form φ of weight $k - 1$ and level N. Further, using the differential operator D_2, they also associate a cusp form of weight $k + 2$ and level N, for a given Jacobi form in the kernel. In this work, we extend this result to Jacobi forms of half-integral weight. We are trying to get these type of results for Jacobi forms of higher index. This is a joint work with B. Ramakrishnan and the work is in progress.

3 Correspondence between Jacobi Forms and Modular Forms
Work is in progress to generalise the results of K. Bringmann on the coresspondence between Jacobi forms of higher degree and Modular forms of integral weight.

Preprints:

1. B. Ramakrishnan and Karam Deo Shankhadhar, *Non-vanishing of L-Functions associated to cusp forms of half-integral weight inside the critical strip* (in preparation).

Conference/Workshops Attended:

1. *Besse Summer School on Quasimodular forms*, Besse et Saint-Anastaise, France, 20-26 June,2010.

2. *ICM Satellite Conference on Modular forms*, Mahabalipuram (near Chennai), India, 1-9 August,2010.

3. *International Congress of Mathematicians*, Hyderabad, India, 19-27 August,2010.

4. *ICM Satellite Conference on Analytic and Combinatorial Number Theory*, IMSc, Chennai, India, 29th August-3rd September,2010.

5. *Winter school on Number Theory (Waring's Problem)*, IISER-Kolkata, Kolkata, India, 13-17 December,2010.

6. *School and Conference on Modular Forms and Mock Modular Forms and their Applications in arithmetic, Geometry and Physics*, ICTP, Trieste, Italy, 28th February-18th March,2011.

Visits to other Institutes:

1. The Institute of Mathematical Sciences, Chennai, India, 10-17 August 2010 and 20th March-2nd April 2011.

Other Activities:

1. Took tutorial classes for IISER-Kolkata winter school on Number Theory (Waring's Problem), 13-17 December,2010.

Vijay Kumar Sohani

Research Summary:

I am working in the area of harmonic analysis. I have been working on well posedness of non-linear schrödinger equation associated to the special Hermite operator for a class of nonlinearities, including power type non linearities on $\mathbb{C}^n$.

Preprints:

1. P.K. Ratnakumar, Vijay Kumar Sohani, *Non-linear Schrödinger equation for the special Hermite operator* (in preparation).

Conference/Workshops Attended:

1. *International Congress of Mathematicians*, Hyderabad,19-27 August,2010.
2. *Satellite Conference on Harmonic Analysis*,NISER, Bhubaneswar,August 29-September 2,2010.

Other Activities:

1. Delivered a talk on *Maxima-Minima and Tracing of Curves* in Rajbhasha Scientific Workshop (for class 11th and 12th students), HRI, Allahabad, 12-16 July 2010.

Ashish Gupta

Research Summary:

The structure of modules over twisted group algebras $F*A$ of a free finitely generated abelian group A over a field F were investigated using a recently introduced geometric invariant – the Δ-set. Noncommutative polynomial rings of this kind are of considerable importance for noncommutative geometry. The Δ-set was used in the commutative case by R. Bieri and R. Strebel to give a criterion for a meta-abelian group to be finitely presented.

Preprints:

1. Gupta A., *A note on simple modules over McConnell–Pettit algebras,* arXiv:1106.4459v1

2. Gupta A., *Modules over quantum Laurent polynomials II,* (in preparation)

Invited Lectures/Seminars:

1. *Quantum Polynomials*, Harish-Chandra Research Institute, Allahabad, April 2011.

Rajesh Kumar Srivastava

Research Summary:

My primary research interests lie in the area of harmonic analysis. Specially, I am working for integral geometry on the Heisenberg group, real hyperbolic spaces etc. The integral geometry is dealt with the problems of determining the function which integrates to zero over a rich family of submanifolds. These ideas have many applications in image processing, medical tomography, geophysics etc. I did the problems of the following nature during my HRI visit since March 2010.

1. Any Coxeter system of even number of lines is a set of injectivity for the twisted spherical means (TSM) on complex plane $\mathbb{C}$ (which naturally arises in the study of spherical means on Heisenberg group). The problem for any Coxeter system of odd number of lines can be a set of injectivity for the TSM is being conjectured by us. This result is quite explicit and adverse to the known result for the spherical means on $\mathbb{R}^2$, due to Agranovsky and Quinto (1996). Our result reveals that the Agranovsky-Quinto conjecture, "the sets of non-injectivity for the spherical means on $\mathbb{R}^n$ $(n \geq 2)$ are contained in a certain algebraic variety" does not continue to hold for the spherical means on the Heisenberg group $\mathbb{H}^1 = \mathbb{C} \times \mathbb{R}$.

2. We have just started to locate the sets of non-injectivity for the spherical means on real hyperbolic spaces $\mathbb{B}^n$ $(n \geq 2)$. To characterize all sets of non-injectivity for the spherical means on $\mathbb{B}^n$, is an open problem. To begin with, we have just shown that sets of non-injectivity for the spherical means on $\mathbb{B}^n$ are contained in the zero set of a certain eigenfunction of the Laplace-Beltrami operator. However, it remains difficult to show that what exactly are the sets of non-injectivity for the spherical means on $\mathbb{B}^n$. We are working in this direction.

Publications:

1. R. K. Srivastava and R. Rawat, *Spherical means in annular regions in the n-dimensional real hyperbolic spaces*, Proc. Indian Acad. Sci. Math. Sci. (**accepted**), DOI: arXiv:0908.2289v1

Preprints:

1. R. K. Srivastava, *Sets of injectivity for weighted twisted spherical means and support theorems*, (communicated). DOI: arXiv:1012.5167v1

2. R. K. Srivastava, *Coxeter system of lines are sets of injectivity for the twisted spherical means on* $\mathbb{C}$, (communicated). DOI: arXiv:1103.4571v1

Conference/Workshops Attended:

1. *Analysis and Applications: A Conference in Honor of Elias M. Stein on the occasion of his 80th birthday,* held at the Department of Mathematics, Princeton University, USA, during May 16–20, 2011.

2. *International Satellite Conference on Harmonic analysis,* NISER, Bhubaneswar, during Aug 29 to Sep 2, 2010.

3. *International Congress of Mathematicians*, held at Hyderabad during Aug 19–27, 2010.

Visits to other Institutes:

1. Visited to the Dept. of Mathematics, Indian Institute of Science, Bangalore, during Nov. 24 to Dec. 06, 2010.

Invited Lectures/Seminars:

1. Given a talk on *Spherical means in annular regions in the Heisenberg group,* at IISER, Bhopal, on 24th March, 2010.

2. Given a talk on *Spherical means in annular regions in the Heisenberg group,* at IISER, Mohali, on 08th Feb., 2010.

3. Given a talk on *Spherical means in annular regions in Heisenberg group and real hyperbolic spaces,* in the 11th Discussion meeting in Harmonic Analysis, held at NISER, Bhubaneswar during Jan 6–9, 2010.

Academic recognition/Awards:

- Awarded the Dr. D. S. Kothari postdoctoral fellowship by the University Grand Commission of India, in June, 2010.

- Awarded the postdoctoral fellowship by the National Board of Higher Mathematics of India, in April, 2010.

Academic Report - Physics

Sandhya Choubey

Research Summary:

Understanding of why there is more matter than antimatter in the universe is of paramount importance as this holds the key to the very existence of the universe. Had there been no matter to antimatter asymmetry, the two would have exactly annihilated each other and the universe would have not existed. Data from the cosmic microwave background radiation and the primordial abundance measurements have now given us rather precise measurement of the excess of baryon over antibaryons – baryons being the fundamental building blocks of nature which participate in strong interactions. This observed baryon asymmetry of the universe requires models beyond the standard paradigm of particle physics.

Another outstanding discovery of the past decade was the existence of neutrino mass and mixing which clearly demands a theory beyond the standard model of particle physics. The observation of very small neutrino masses, at least a dozen orders of magnitude lower than the top quark mass, poses a challenge for building a model which accounts for the masses of elementary particles. Since the Standard Model (SM) of particle physics fails to provide any explanation for the neutrino masses, one is forced to look beyond. 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. The see-saw mechanism for generating Majorana masses for the neutrinos opens up another appealing possibility. It allows creation of a lepton asymmetry in the early universe as a result of CP violating out-of-equilibrium decay of the heavy see-saw mediating particle a phenomenon called leptogenesis. This lepton asymmetry can be subsequently converted to a baryon asymmetry through the B?L conserving and B+L violating sphaleron processes, which are important at temperatures following the epoch of leptogenesis. The see-saw mechanism therefore offers a very natural explanation for baryogenesis through leptogenesis.

Existence of CP asymmetry in the heavy right-handed neutrino decays is

a prerequisite for leptogenesis within the type I see-saw mechanism. CP violation might also be discovered in the upcoming and planned neutrino oscillation experiments. The see-saw mechanism that gives the low energy neutrino mass matrix is also responsible for leptogenesis. Therefore, people have attempted to connect the low energy CP violation with the CP asymmetry in leptogenesis. In a work done with my student Manimala Mitra and Steve King, we emphasized that the vanishing of the CP asymmetry in leptogenesis, previously observed for models with so-called tri-bimaximal mixing and family symmetry, may be traced to a property of the type I see-saw mechanism satised by such models known as Form Dominance, corresponding to the case of a diagonal Casas-Ibarra R matrix. Form Dominance leads to vanishing avour-dependent CP asymmetries irrespective of whether one has tri-bimaximal mixing or a family symmetry. Successful leptogenesis requires violation of Form Dominance, but not necessarily violation of tri-bimaximal mixing. This may be achieved in models where the family symmetry responsible for tri-bimaximal mixing is implemented indirectly and a strong neutrino mass hierarchy is present with the Form Dominance broken only softly by the right-handed neutrino responsible for the lightest neutrino mass, as in constrained sequential dominance.

The SU(5) GUT model extended with fermions in the adjoint 24_F representation predicts triplet fermions in the 100 GeV mass range, opening up the possibility of testing seesaw at LHC. However, once the model is supersymmerized, the triplet fermion mass is constrained to be close to the GUT scale for the gauge couplings to unify. In a paper with my students Manimala Mitra and Ram Lal Awasthi we proposed an extension of the SUSY SU(5) model where type II seesaw can be tested at LHC. In this model we added a matter chiral field in the adjoint $\hat{24}_F$ representation and Higgs chiral superfields in the symmetric $\hat{15}_H$ and $\hat{\bar{15}}_H$ representations. We call this the symmetric adjoint SUSY SU(5) model. The triplet scalar and triplet fermion masses in this model are predicted to be in the 100 GeV and 10^{13} GeV range respectively, while the mass of the singlet fermion remains unconstrained. This gives a type I plus type II plus type III seesaw mass term for the neutrinos. The triplet scalars with masses ~ 100 GeV range can be produced at the LHC. We briefly discussed the collider phenomenology and predictions for proton decay in this model.

In another work done with Raj Gandhi, Atsushi Watanabe and Atri Bhattacharyya, we examined how light neutrinos coming from distant active galactic nuclei (AGN) and similar high energy sources may be used as tools to probe non-standard physics. In particular we discussed how study-

ing the energy spectra of each neutrino flavour coming from such distant sources and their distortion relative to each other may serve as pointers to exotic physics such as neutrino decay, Lorentz symmetry violation, pseudo-Dirac effects, CP and CPT violation and quantum decoherence. This lead us to probe hitherto unexplored ranges of parameters for the above cases, for example lifetimes in the range $10^{-3} - 10^{4}$ s/eV for the case of neutrino decay. We showed that standard neutrino oscillations ensure that the different flavours arrive at the earth with similar shapes even if their flavour spectra at source may differ strongly in both shape and magnitude. As a result, observed differences between the spectra of various flavours at the detector would be signatures of non-standard physics altering neutrino fluxes during propagation rather than those arising during their production at source. Since detection of ultra-high energy (UHE) neutrinos is perhaps imminent, it is possible that such differences in spectral shapes will be tested in neutrino detectors in the near future. To that end, using the IceCube detector as an example, we showed how our results translate to observable shower and muon-track event rates.

Collective flavor oscillations are known to bring multiple splits in the supernova (SN) neutrino and antineutrino spectra. These spectral splits depend not only on the mass hierarchy of the neutrinos but also on the initial relative flux composition. With Basudeb Dasgupta, Amol Dighe and Alessandro Mirizzi, we calculate the expected galactic supernova neutrino signal at large next-generation underground detectors. At different epochs after the explosion, the primary fluxes can be quite different. For these primary neutrino fluxes, spectral splits induced by collective neutrino flavor transformations can arise for either mass hierarchy in both neutrino and antineutrino channels. We classify flux models according to the nature and number of these splits, and calculate the observable electron-neutrino and electron-antineutrino spectra at Earth, taking into account subsequent matter effects. We found that some of the spectral splits could occur sufficiently close to the peak energies to produce significant distortions in the observable SN neutrino signal. The most striking signature of this effect would be presence of peculiar energy dependent modulations associated with Earth matter crossing, present only in portions of the SN neutrino energy spectra demarcated by spectral splits. These signatures at proposed large water Cherenkov, scintillation, and liquid Argon detectors could give hints about the primary SN neutrino fluxes, as well as on the neutrino mass hierarchy and the mixing angle θ_{13}.

Observation of spectral splits in a future galactic supernova signal is expected to throw light on the mass hierarchy pattern of the neutrinos. How-

ever, since the Diffuse Supernova Neutrino Background (DSNB) comprises of a superposition of neutrino fluxes from all past supernovae, and since different supernovae are expected to have slightly different initial fluxes, it is pertinent to check if the hierarchy dependent signature of collective oscillations can survive this averaging of the flux spectra. In a work with Sovan Chakraborty and Kamales Kar we made this study. Since the actual distribution of SN with initial relative flux spectra of the neutrinos and antineutrinos is unknown, we assumed a log-normal distribution for them. We studied the dependence of the hierarchy sensitivity to the mean and variance of the log-normal distribution function. We found that the hierarchy sensitivity depends crucially on the mean value of the relative initial luminosity. The effect of the width is to reduce the hierarchy sensitivity for all values of the mean initial relative luminosity. We found that in the very small mixing angle (θ_{13}) limit considering only statistical errors even for very moderate values of variance, there is almost no detectable hierarchy sensitivity if the mean relative luminosities of ν_e and $\bar{\nu}_e$ are greater than 1.

Publications:

1. S. Choubey, S. F. King and M. Mitra, *On the Vanishing of the CP Asymmetry in Leptogenesis due to Form Dominance,* Phys. Rev. D **82**, 033002, (2010)

2. A. Bhattacharya, S. Choubey, R. Gandhi and A. Watanabe, *Ultra-high neutrino fluxes as a probe for non-standard physics,* JCAP **1009**, 009, (2010)

3. A. Bhattacharya, S. Choubey, R. Gandhi and A. Watanabe, *Diffuse Ultra-High Energy Neutrino Fluxes and Physics Beyond the Standard Model,* Phys. Lett. B **690**, 42, (2010)

4. S. Chakraborty, S. Choubey, S. Goswami and K. Kar, *Collective Flavor Oscillations Of Supernova Neutrinos and r-Process Nucleosynthesis,* JCAP **1006**, 007, (2010)

5. S. Choubey and M. Mitra, *Spontaneous R-Parity Violating Type III Seesaw,* JHEP **1005**, 021, (2010)

6. S. Choubey, T. Schwetz and C. Walter, *Working Group 1 Report (Theory),* AIP Conf. Proc. **1222**, 65 (2010)

Preprints:

1. S. Chakraboty, S. Choubey and K. Kar, *On the Observability of Collective Flavor Oscillations in Diffuse Supernova Neutrino Background,* arXiv:1006.3756 [hep-ph]

2. S. Choubey, B. Dasgupta, A. Dighe and A. Mirizzi, *Signatures of collective and matter effects on supernova neutrinos at large detectors,* arXiv:1008.0308 [hep-ph]

3. R. L. Awasthi, S. Choubey and M. Mitra, *Probing Seesaw in an Adjoint SUSY SU(5) Model at LHC,* arXiv:1009.0509 [hep-ph]

4. M. Wurm *et al.* [LENA Collaboration], *The next-generation liquid-scintillator neutrino observatory LENA,*arXiv:1104.5620 [astro-ph.IM]

5. S. Choubey, T. Schwetz and C. Walter, *Working Group 1 Report (Theory),* to appear in the proceedings of the NuFact10, TIFR, Mumbai, October 2010

Conference/Workshops Attended:

1. *Neutrino Oscillation Workshop*, Italy, September, 2010

2. *CERN Theory Institute, ν TheME: Neutrino Theory, Models, and Experimental Perspectives*, Switzerland, September, 2010

3. *12th International Workshop on Neutrino Factories, Superbeams and Beta Beams*, India, October, 2010

4. *Neutrinos in Physics, Astrophysics and Cosmology*, India, February, 2010

5. *7th International Workshop on Neutrino-Nucleus Interaction in the Few-GeV Region, NuInt 2011*, India, March 2011

Invited Lectures/Seminars:

1. *Phyics with ICAL@INO*, 7th International Workshop on Neutrino-Nucleus Interaction in the Few-GeV Region, NuInt 2011, Dehradun, India, March, 2011.

Other Activities:

1. Organizing schools/conferences:
   (a) Member of the International Advisory Committee, XIV International Workshop on Neutrino Telescopes, Venice, Italy, March, 2011.
   (b) Converner of the Neutrino Oscillation Physics (WG1) of the 12th International Workshop on Neutrino Factories, Superbeams and Betabeams, NuFact11, TIFR, India, October, 2011.
   (c) Regional convener for the physics and performance evaluation group (PPEG) of the International Design Study for the Neutrino Factory (IDS-NF, www.ids-nf.org)
   (d) Member of the National Organizing Committee of the "7th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region", NUINT11, Dehradun, India, March 2011.
   (e) Member of the organizing committee of "NuHoRIzons, Neutrinos in Physics, Astrophysics and Cosmology", held at HRI, Allahabad, February 2011.
2. Teaching at HRI: Fourth semester course on "Computational Methods", 2011.
3. Mentoring PhD Students:
   (a) Anushree Ghosh (registered with India-based Neutrino Obeservatory)
   (b) Ram Lal Awasthi
4. Reviewing Papers: Refereed papers for
   (a) Physical Review Letters
   (b) Physical Review D
   (c) Journal of High Energy Physics
   (d) Physica Scripta.
   (e) New Journal of Physics
5. Committees Served:
   (a) Office and Furniture Committee (Convener)
   (b) Women Grievance Cell (Convener)

Tirthankar Roy Choudhury

Research Summary:

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 reionization history of the Universe using a variety of data sets, (ii) optical strategies for detecting the signal from cosmological neutral hydrogen at different redshifts, (iii) detailed modelling of the intergalactic medium through Lyα forest at redshifts $z \sim 3$ and it consequences for double reionization of helium.

Publications:

1. Susumu Inoue, Ruben Salvaterra, Tirthankar Roy Choudhury, Andrea Ferrara, Benedetta Ciardi, Raffaella Schneider, *Probing intergalactic radiation fields during cosmic reionization through gamma-ray absorption,* Monthly Notices of the Royal Astronomical Society **404**, 1938, (2010)

2. Tapomoy Guha Sarkar, Somnath Bharadwaj, Tirthankar Roy Choudhury, Kanan Datta, *Cross-correlation of the HI 21-cm signal and Lyα forest: a probe of cosmology,* Monthly Notices of the Royal Astronomical Society **410**, 1130, (2011)

Preprints:

1. Suman Majumdar, Somnath Bharadwaj, Kanan K. Datta, T. Roy Choudhury, *The impact of anisotropy from finite light travel time on detecting ionized bubbles in redshifted 21-cm maps,* arXiv:1006.0430

2. Girish Kulkarni, T. Roy Choudhury, *Reionization and feedback in overdense regions at high redshift,* arXiv:1008.2509

3. Sourav Mitra, T. Roy Choudhury, Andrea Ferrara, *Reionization constraints using Principal Component Analysis,* arXiv:1011.2213

Conference/Workshops Attended:

1. *Cosmology Rapid Response Meeting*, TIFR, India, April, 2010.

2. *Summer School on Gravitation and Cosmology*, HRI, India, May, 2010.

3. *Primordial Features and Non-Gaussianities*, HRI, India, December, 2010.

4. *The Twenty Sixth Meeting of the Indian Association for General Relativity and Gravitation: Sangam: Confluence of Gravitation and Cosmology*, HRI, India, January, 2011.

5. *School on Recent Advances in Cosmology*, Siliguri, India, February, 2011.

6. *29th Scientific Meeting of Astronomical Society of India*, Raipur, India, February, 2011.

7. *Emerging Trends in Gravitation and Cosmology*, Jadavpur University, India, March, 2011.

Visits to Other Institutes:

1. IUCAA, Pune, India, April, 2010

Invited Lectures/Seminars:

1. *Constraints on reionization physics from CMBR and other observations*, Cosmology Rapid Response Meeting, TIFR, Mumbai, India, April 2010.

2. *Lectures on Perturbed Universe*, Summer School on Gravitation and Cosmology, HRI, Allahabad, India, May 2010.

3. *Big Bang Cosmology: The Four Pillars*, Summer School on Gravitation and Cosmology, HRI, Allahabad, India, May 2010.

4. *Lectures on Cosmological Reionization*, School on Recent Advances in Cosmology, NBU, Siliguri, India, February, 2011.

5. *Cosmological Reionization*, 29th Scientific Meeting of Astronomical Society of India, PRSU, Raipur, India, February, 2011.

6. *Dark Ages and Reionization: Final Frontier of Observational Cosmology*, Emerging Trends in Gravitation and Cosmology, RCRC, Jadavpur University, India, March, 2011.

Other Activities:

1. Member, Graduate Studies Committee (Physics) and Computer Committee.
2. PhD supervision: Sourav Mitra (HRI)
3. Full-semester course on *Mathematical Physics* in the for graduate students in Physics, August-December 2010.
4. Masters' Thesis: Abhinav Agrawal (BITS, Pilani), January-May 2011.
5. Bachelors Internship: Vaibhav Sharma (IIIT, Allahabad), January-May 2011.
6. VSP Projects: Rituparno Mandal, Arkajyoti Dhar, October 2010.

Tapas Kumar Das

Research Summary:

Relativistic and high energy astrophysics, with particular emphasis on accretion phenomena around black holes and related issues – quasi periodic oscillations as observed in the galactic and the extra galactic sources, for example. Application of the theory of dynamical systems in astrophysical flow.

Publications:

1. Czerny, B., Lachowicz, P., Dovčiak, M., Karas, V., Pecháček, T., & Das, T. K., *The model constraints from the observed trends for the quasi-periodic oscillation in RE J1034+396,* Astronomy and Astrophysics **524**, id.A26, (2010)

2. Das, T. K., *Behaviour of Relativistic Matter Close to the Black Hole Event Horizon,* Proc. Astronomical Society of the Republic of China 2010 Scientific Assembly ASROC2010, (2010)

3. Das, T. K., & Czerny, B., *Modeling the time-resolved quasi-periodic oscillations in active galactic nuclei,* Monthly Notices of the Royal Astronomical Society **Online Early Version**, DOI: 10.1111/j.1365-2966.2011.18427.x, (2011)

4. Das, T. K., & Czerny, B., *Hysteresis effects and diagnostics of the shock formation in low angular momentum axisymmetric accretion in the Kerr metric,* New Astronomy **In Press**, (2011)

5. Nag, S., Acharya, S., Ray, A. K., & Das, T. K., *The role of flow geometry in influencing the stability criteria for low angular momentum axisymmetric black hole accretion,* New Astronomy **In Press**, (2011)

Conference/Workshops Attended:

1. *Astronomical Society of the Republic of China 2010 Scientific Assembly*, Taiwan, May, 2010.

Visits to other Institutes:

1. Institute of Astronomy and Astrophysics Academia Sinica, Taipei, Taiwan, May - July 2010.
2. National Taiwan Normal University, Taipei, Taiwan, June 2010.
3. National Tsing Hua University, Hsinchu, Taiwan, June 2010.
4. National Central University, Chungli, Taiwan, July 2010.
5. Institute of Physics, Academia Sinica, Taipei, Taiwan, July 2010.
6. Chulalongkorn University, Bangkok, Thailand, August 2010.
7. Centre for Relativity and Cosmology, Jadavpur University, Calcutta, India, March 2011.
8. Saha Institute of Nuclear Physics, Calcutta, India, March 2011.

Invited Lectures/Seminars:

1. *Low Angular Momentum Accretion Phenomena*, Circumstellar Astrophysics Meeting, Institute of Astronomy, Academia Sinica, Taipei, Taiwan, May, 2010.
2. *Behaviour of Relativistic Matter Close to the Black Hole Event Horizon*, Astronomical Society of the Republic of China 2010 Annual Meeting, Institute of Astronomy, Academia Sinica, Taipei, Taiwan, May, 2010.
3. *Analogue Gravity Phenomena*, Theoretical Physics Colloquium, Department of Physics, National Taiwan Normal University, Taipei, Taiwan, June, 2010.
4. *Emergent metric in classical and quantum fluid*, Theoretical Physics Seminar, Theoretical High Energy Physics Group, Institute of Physics, Academia Sinica, Taipei, Taiwan, June, 2010.
5. *Accretion onto astrophysical black holes as an Autonomous Dynamical System*, Astronomy Colloquium, National Tsing Hua University, Hsinchu, Taiwan, June, 2010.
6. *Application of the sub-Keplarian flow to the Galactic Centre black hole accretion*, Group Seminar, Department of Earth Science and Astronomy, National Taiwan Normal University, Taipei, Taiwan, July, 2010.

7. *Behaviour of Matter Close to the Event Horizon*, Astronomy Colloquium, National Central University, Chungli, Taiwan, July, 2010.

8. *Black Hole Accretion: A Dynamical Systems Approach*, Computational Fluid Dynamics and Star Formation Group Seminar, Institute of Astronomy, Academia Sinica, Taipei, Taiwan, July, 2010.

9. *Astrophysical Black Holes: Laboratories to Test the Theory of Relativity*, Lecture for Summer Students Programme, Institute of Astronomy, Academia Sinica, Taipei, Taiwan, July, 2010.

10. *On the role of black hole spin in influencing the behaviour of transonic accretion*, Colloquium, Institute of Astronomy, Academia Sinica, Taipei, Taiwan, July, 2010.

11. *How to study the astrophysical accretion from a dynamical systems approach*, A two lecture series, Department of Physics, Chulalongkorn University Bangkok, Thailand, August, 2010.

12. *Imaging the black hole event horizon*, seminar at Centre for relativity and cosmology, Jadavpur University, Kolkata India, March 2011.

13. *Portrait of a dark face*, seminar at Saha Institute of Nuclear Physics, Kolkata India, March 2011.

Academic recognition/Awards:

- Appointed as a member of the editorial board of the Journal of Astronomy and Space Sciences (`http://janss.kr/main/default.asp`), an international journal published by the Korean Space Science Society.

Other Activities:

1. **International Proposal Reviewer**

   (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.

2. **Journal Referee**

(a) Served as a referee for several papers submitted in various International journals, like Classical and Quantum Gravity for example.

3. **Mentoring Students**

   (a) Priyanka Debnath, from Calcutta University, India.

   (b) Arpita Choudhary, from Lucknow University, India.

   (c) Soumitra Bhattacharya, from Presidency College, Calcutta.

   (d) Hung Yi Pu, from National Tsing Hua University, Taiwan.

4. **KVPY Interview**

   (a) Member of the interview panel for the Kishore Vaigyanik Protashana Yojana (KVPY).

5. **Teaching**

   (a) Graduate Course: Astrophysical Processes, August - December 2010.

6. **Administrative Work**

   (a) Served as a member of the Medical Advisory Committee at HRI.

   (b) Served as a member of the Security Committee at HRI

AseshKrishna Datta

Research Summary:

Collider searches of physics beyond the Standard Model (SM) of particle physics with particular emphasis on physics studies for the ongoing experiments at the Large Hadron Collider (LHC) at CERN, Geneva, Switzerland. Engaged in studies of early, and near-future possibilities at the LHC in reference to the third generation scalar excitations of weak scale Supersymmetry. In the process of developing an integrated framework for state-of-the-art phenomenological studies at the LHC taking into account the SM backgrounds as precisely as possible.

Publications:

1. AseshKrishna Datta, Kyoungchul Kong, Konstantin T. Matchev, *Minimal Universal Extra Dimensions in CalcHEP/CompHEP,* New J.Phys. **12**, 075017, (2010), published in July, 2010.

Conference/Workshops Attended:

1. *Dark Matter in LHC Era: Direct & Indirect Searches, SINP, Kolkata, January, 2011.*

2. *Discussion Meeting on LHC, Santiniketan, January, 2011.*

3. *National Conference on Particle Physics and Cosmology, University of Burdwan, March, 2011.*

Visits to other Institutes:

1. Visited the Theoretical Physics Group, Indian Association for the Cultivation of Science, Kolkata during May-June, 2011.

Invited Lectures/Seminars:

Invited to give a talk that includes a pedagogic discussion related to observable quantities pertaining to dark matter search at LHC at the conference *Dark Matter in LHC Era: Direct & Indirect Searches, SINP, Kolkata, January, 2011.* Invitation declined under the impression of not being the right person for the topic proposed.

Other Activities:

1. **Journal Referee**

   (a) Served as a referee for Physical Review D during this report period.

2. **Mentoring Students**

   (a) Saurabh Niyogi, Ph.D. student in his third year.

3. **Teaching**

   (a) Graduate Course: Classical Mechanics, August - December 2010.

4. **Member of external bodies**

   (a) Served as a member of the National Advisory Committee of National Conference on Particle Physics and Cosmology, University of Burdwan, March, 2011.

5. **Administrative Work**

   (a) Served as the convener of the Computer Committee at HRI.

   (b) Served as the convener of the Sports and Entertainment Committee at HRI.

   (c) Served as a member of the project-committee for High Performance Scientific Computing at HRI.

   (d) Served as the Technical Coordinator of the of the Regional Centre for Accelerator-based Particle Physics (RECAPP) at HRI.

Aditi Sen De

Research Summary:

My field of study is quantum information science and its interface with other sciences, like ultracold gases, condensed matter physics, and quantum optics. Below I present a selection of the areas in which I have been working in the past year.

Atom counting theory can be used to study the role of thermal noise in quantum phase transitions and to monitor the dynamics of a quantum system. We have illustrated this for a strongly correlated fermionic system, which is equivalent to an anisotropic quantum XY chain in a transverse field, and can be realized with cold fermionic atoms in an optical lattice. We analyzed the counting statistics across the phase diagram in the presence of thermal fluctuations, and during its thermalization when the system is coupled to a heat bath. Moreover, we have also studied the counting statistics of ultracold bosonic atoms that are released from an optical lattice. We have shown that the counting probability distribution of the atoms collected at a detector located far away from the optical lattice can be used as a method to infer the properties of the initially trapped states.

During the last year, we have also related measures of quantum correlation defined from an information-theoretic perspective, viz., quantum discord and quantum work-deficit, with the entanglement of the infinite anisotropic quantum XY spin chain, in a transverse time-dependent field. We have shown that both the measures can be associated with the collapse and revival of nearest-neighbor entanglement in a dynamical phase transition present in the time-evolution of the system. In particular, we found that revival of entanglement of the evolved state happens if there is an increase in quantum discord in the vicinity of entanglement collapse.

Correlations between the parts of a many-body system, and its time dynamics, lie at the heart of sciences, and they can be classical as well as quantum. Quantum correlations are traditionally viewed as constituted out of classical correlations and magnetizations. While that of course remains so, we have shown that quantum correlations can have statistical mechanical properties like ergodicity, which is not inherited from the corresponding classical correlations and magnetizations, for the transverse anisotropic quantum XY model in one-, two-, and quasi two-dimension. The results have the potential for applications in decoherence effects in realizable quantum computers.

Publications:

1. Aditi Sen(De) and Ujjwal Sen, *Quantum Advantage in Communication Networks*, Physics News **40**, 17 (2010).

2. Sibylle Braungardt, Mirta Rodríguez, Aditi Sen(De), Ujjwal Sen, Roy J. Glauber, and Maciej Lewenstein, *Counting of fermions and spins in strongly correlated systems in and out of thermal equilibrium*, Phys. Rev. A **83**, 013601 (2011).

Preprints:

1. Aditi Sen(De) and Ujjwal Sen, *Cluster Entanglement Mean Field inspired approach to Criticality in Classical Systems*, arXiv:1008.0965.

2. Himadri Shekhar Dhar, Rupamanjari Ghosh, Aditi Sen(De), and Ujjwal Sen, *Quantum Discord Surge Heralds Entanglement Revival in an Infinite Spin Chain*, arXiv:1011.5309.

3. Sibylle Braungardt, Mirta Rodríguez, Aditi Sen(De), Ujjwal Sen, and Maciej Lewenstein, *Atom Counting in Expanding Ultracold Clouds*, arXiv:1103.1868.

4. R. Prabhu, Aditi Sen(De), Ujjwal Sen, *Ergodicity from Nonergodicity in Quantum Correlations of Low-dimensional Spin Systems*, arXiv:1103.3836.

5. Aditi Sen(De) and Ujjwal Sen, *Benford's Law: Detection of Quantum Phase Transitions similarly as Earthquakes*, arXiv:1103.5398.

Conference/Workshops Attended:

1. *Workshop on Quantum Chaos and Quantum Information*, Chennai, India, July 2010.

2. *International Conference on Statistical Physics, STATPHYS - KOLKATA VII*, Kolkata, India, November 2010.

3. *International School and Conference on Quantum Information Processing and Applications (QIPA-2011)*, Allahabad, India, February 2011.

Invited Lectures/Seminars:

1. *Distributed Quantum Information Processing*, Invited seminar, Korea Institute for Advanced Study (KIAS), Seoul, South Korea, June 2010.

2. *Distributed Quantum Information Processing*, Invited talk in the Workshop on Quantum Chaos and Quantum Information, Indian Instituite of Technology Madras, Chennai, India, July 2010.

3. *Collapse and Revival of Quantum Correlations in a Quantum Spin Chain*, Invited talk in the International Conference on Statistical Physics, STATPHYS - KOLKATA VII, Saha Institute of Nuclear Physics, Kolkata, India, November 2010.

Visits to other Institutes:

1. Korea Institute for Advanced Study (KIAS), Seoul, South Korea, June-July 2010.

2. School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India, July 2010.

3. Saha Institute of Nuclear Physics, Kolkata, India, December 2010.

Other Activities:

1. Guided projects of two second-year HRI graduate students, Shrobona Bagchi and Avijit Misra, entitled "Entanglement Measures", Aug-Dec 2010, and a first-year HRI graduate student, Udit Narayan Chowdhury, entitled "On Leggett's Inequality" during Jan-May 2011.

2. Organizer of the "International School and Conference on Quantum Information Processing and Applications (QIPA-2011)" held at HRI during 14-20 February 2011, along with three other members of HRI. [www.hri.res.in/˜qipa11/]

3. Guided projects of two students, Lavisha Jindal and Debashis Sadhukhan, during May-June 2010, through the visiting students programme (VSP) of HRI.

4. Member of Graduate Studies and Admission Committee (JEST), Women's Grievence Cell, and Auditorium Committee at HRI.

5. Served as referees in several international journals.

Rajesh Gopakumar

Research Summary:

With Matthias Gaberdiel and other collaborators, we have been studying theories on three dimensional Anti-de Sitter space (AdS_3) to better understand this particular case of the AdS/CFT correspondence which involves the relatively tractable 2d CFTs. Building on previous work with Justin David and Gaberdiel, we applied the expressions for the one loop determinants for arbitrary spin fields in AdS_3 to study the case of higher spin gauge fields. In particular, with Arunabha Saha we computed the one loop contribution (on thermal AdS_3) for a higher spin gauge field of spin $s \geq 2$. We showed then that the answer (for a set of higher spin fields of spins $s = 2 \ldots N$) is consistent with a $\mathcal{W}_N$ asymptotic symmetry algebra on the boundary. This gives evidence for the quantum relaisation of the $\mathcal{W}_N$ symmetry.

With Gaberdiel we then proposed a duality for a specific higher spin theory of the Vasiliev kind (i.e. with spins $s = 2 \ldots \infty$) coupled to two complex scalar fields. The proposed dual is the large N, 'tHooft limit of a series of non-supersymmetric 2d CFTs which possess $\mathcal{W}_N$ symmetry. These latter are the so-called $\mathcal{W}_N$ minimal models which are generalisations of the famous Virasoro unitary minimal models that describe, among others, the 2d Ising model at criticality. We gave some evidence for this duality in our original paper and have since provided much stronger evidence. This promises to be a fruitful line of investigation which we intend to pursue in the coming year as well. We are also pursuing the study of higher spin theories in higher dimensions. To this end, with Rajesh Gupta and Shailesh Lal we have computed the one loop determinants for arbitrary spin fields in general odd dimensional AdS spacetimes.

Another line of investigation that I have been pursuing is that of trying to derive the AdS/CFT duality from general grounds. In this direction we have been trying to find simple enough examples where such a duality may be exhibited explicitly. One such example which I have been studying is that of the Gaussian matrix model which is one of the simplest large N theories to study. I have proposed a specific way in which the Feynman diagrams for correlators in this theory can be reorganised into closed string amplitudes. With this prescription one finds that the closed string theory in this case is that of the A-model topological string theory on P^1. We supplied some direct evidence for such a relation as well. I am currently trying to understand better various aspects of this proposed duality

and the generalisations thereof with a view to better coming to grips with the general AdS/CFT correspondence.

Publications:

1. A. Bagchi, R. Gopakumar, I. Mandal and A. Miwa, *GCA in 2d*, JHEP **1008**, 004, (2010).

2. M. R. Gaberdiel, R. Gopakumar and A. Saha, *Quantum W-Symmetry in AdS_3*, JHEP **1102**, 004, (2011).

3. M. R. Gaberdiel and R. Gopakumar, *An AdS_3 Dual for Minimal Model CFTs*, Phys. Rev. **D83**, 066007, (2011).

Preprints:

1. R. Gopakumar, R. K. Gupta and S. Lal, *Heat Kernel for AdS_{2n+1}*, arXiv:1102.3627 [hep-th].

2. R. Gopakumar, *What is the Simplest Gauge-String Duality?*, arXiv:1103.2386 [hep-th].

Conference/Workshops Attended:

1. *Wits Workshop on Gauge theories and String Theories*, University of Witwatersrand, Johannesburg, South Africa, Apr. 2010.

2. *LPTHE-ENS Mini-String Conference*, Paris, Jun. 2010.

3. Mid-Year Meeting, Indian Academy of Sciences, Bangalore, Jul. 2010.

4. *LMS Durham Symposium 2010, Durham*, UK, Jul. 2010.

5. *International Conference on Strings, M-theory and Quantum Gravity*, Ascona, Switzerland, Jul. 2010.

6. *KITPC-CAS Workshop on AdS/CMT*, Beijing, Nov. 2010.

7. *Symposium on Quantum Gravity*, INSA Anniversary Meeting, Bangalore, Dec. 2010.

8. *Indian Strings Meeting 2011*, Puri, Jan. 2011.

9. *Bhubaneshwar Symposium on Noncommutative Geometry, Number Theory and Physics*, IMA, Bhubaneshwar, Jan. 2011.

10. *New Frontiers in Quantum Field Theory*, BHU, Varanasi, Feb. 2011.

11. *QFT 2011*, IISER, Pune, Feb. 2011.

12. *One-Day Seminar on Gravitation and Cosmology*, RKM Vivekananda University, Belur, Mar. 2011.

Visits to other Institutes:

1. CHEP/ICTS-TIFR, Bangalore, Apr-May, 2010.

2. LPTHE, Univ. of Paris, Jussieu, Jun. 2010.

3. Univ. of Amsterdam, Netherlands, Jun. 2010.

4. ETH, Zurich, Jul. 2010.

Invited Lectures/Seminars:

1. *Open-Closed-Open String Duality*, Wits Workshop on Gauge theories and String Theories, University of Witwatersrand, Johannesburg, South Africa, Apr. 2010.

2. *Unravelling the String Dual to the Gaussian Matrix Model*, String Meet, CHEP, IISc, Bangalore, May. 2010.

3. *Unravelling the String Dual to the Gaussian Matrix Model*, LPTHE-ENS Mini-String Conference, Paris, Jun. 2010.

4. *Unravelling the String Dual to the Gaussian Matrix Model*, Theory Seminar, Univ. of Amsterdam, Jun. 2010.

5. *String Theory and the Quest for Quantum Spacetime*, Colloquium, NCBS (TIFR), Bangalore, Jul. 2010.

6. *The Journey from Maxwell to Faraday*. Mid-Year Meeting, Indian Academy of Sciences, Bangalore, Jul. 2010.

7. *Unravelling the String Dual to the Gaussian Matrix Model*, LMS Durham Symposium 2010, Durham, UK, Jul. 2010.

8. *Unravelling the String Dual to the Gaussian matrix Model*, International Conference on Strings, M-theory and Quantum Gravity, Ascona, Switzerland, Jul. 2010.

9. *Higher Spin Theories and AdS/CMT*, KITPC-CAS Workshop on AdS/CMT, Beijing, Nov. 2010.

10. *Quantum Gravity on your Tabletop?*, Symposium on Quantum Gravity, INSA Anniversary Meeting, Bangalore, Dec. 2010.

11. *A Large N Dual to 2d CFT*, Plenary Talk, Indian Strings Meeting 2011, Puri, Jan. 2011.

12. *Gauge-String Duality*, sf Bhubaneshwar Symposium on Noncommutative Geometry, Number Theory and Physics, IMA, Bhubaneshwar, Jan. 2011.

13. *A Large N Dual to 2d CFTs*, New Frontiers in Quantum Field Theory, BHU, Varanasi, Feb. 2011.

14. *A Large N Dual to 2d CFTs*, QFT 2011, IISER, Pune, Feb. 2011.

15. *String Theory and the Quest for Quantum Spacetime*, Seminar on Gravitation and Cosmology, RKM Vivekananda University, Belur, Mar. 2011.

16. *A Large N Dual to 2d CFTs*, Workshop on Holography and Higher Spin Theories, Simons Center for Geometry and Physics, Stony Brook, USA, Mar. 2011 (over skype).

17. *A Large N Dual to 2d CFTs*, Lecture Series at the ICTP Spring School theory on Superstring Theory, ASICTP, Trieste, Mar. 2011.

Academic recognition/Awards:

- Appointed as Adjunct Faculty, ICTS-TIFR (2010-2013)
- Fellow of Global Young Academy of Scientists, 2010

Other Activities:

1. Member, Organising Committee, Indo-US Frontiers of Science Meeting, Irvine, USA, 2011.

2. Member, Organising Committee, ICTS Meeting on Random Matrix Theory and Applications, IISc. Bangalore, (Jan. 2012).

3. Member, Organising Committee, 4th Asian Winter School on String Theory, Particle Physics and Cosmology, Tohuku, Japan (Jan. 2012).

4. Member/Convenor of various academic and administrative committees at HRI.

5. Member, Program Committee, International Centre for Theoretical Sciences (ICTS).

6. Invited Article: *Variational Principles in Physics and Mathematics* in *Math Unlimited* (ed. R. Sujatha) (2011).

Dileep P. Jatkar

Research Summary:

Last one year, I have been looking at the non-relativistic holography in various dimensions. I have mostly looked at Schrödinger geometries either as an effect of fermion backreaction or generated as string backgrounds obtained by using solution generating technique, TsT transformation.

I also studied relation of Born-Infeld gravity in 2+1 dimensions and its relevance to boundary counter-terms for AdS_4 theories.

Publications:

1. Ling-Yan Hung, Dileep P. Jatkar, Aninda Sinha, *Non-relativistic metrics from back-reacting fermions,* Classical and Quantum Gravity **28**, 015013, (2011)

2. Dileep P. Jatkar, Aninda Sinha, *New Massive Gravity and AdS_4 counterterms,* Physical Review Letters **106**, 171601, (2011)

Preprints:

1. Nabamita Banerjee, Suvankar Dutta, Dileep P. Jatkar, *Geometry and Phase Structure of Non-Relativistic Branes,* arXiv:1102.0298

Conference/Workshops Attended:

1. *Indian Strings Meeting 2011*, India, January, 2011

Visits to other Institutes:

1. Perimeter Institute, Waterloo, Canada, April 2010–July 2010; October 2010.

2. Department of Physics, University of Kentucky, Lexington, USA, November 1-4, 2010.

3. ITF, Utrecht University, Utrecht, The Netherlands, November 2010.

4. Albert Einstein Institute, Golm, Germany, December 4-10 2010.

Invited Lectures/Seminars:

1. *New Massive Gravity and AdS_4 counterterms*, String group seminar, Department of Physics, University of Kentucky, Lexington, November 2010.

2. *New Massive Gravity and AdS_4 counterterms*, Group Seminar, ITF, Utrecht, November 2010.

Pinaki Majumdar

Research Summary:

We have completed much of the ongoing work on disorder in the double perovskites and have started on a study of correlated quantum systems using an auxiliary field (Hubbard-Stratonovich) strategy. This will enable us to study the interplay of strong coupling, randomness, and thermal fluctuations in correlated systems in the solid state or cold atoms.

Publications:

1. Viveka Nand Singh and Pinaki Majumdar, *Antisite Domains in Double Perovskite Ferromagnets: Impact on Magnetotransport and Half-metallicity,* Europhys. Lett. **94**, 47004, (2011)

Preprints:

1. Viveka Nand Singh and Pinaki Majumdar, *Antiferromagnetic Order and Phase Coexistence in Antisite Disordered Double Perovskites,* arXiv:1009.1709.

2. Rajarshi Tiwari and Pinaki Majumdar, *Non-collinear Magnetic Order in the Double Perovskites: Double Exchange on a Geometrically Frustrated Lattice,* arXiv:1105.0148.

3. Viveka Nand Singh, Sanjoy Datta, Pinaki Majumdar, *Thermally Fluctuating Inhomogeneous Superfluid State of Strongly Interacting Fermions in an Optical Lattice*, arXiv:1104.4912.

4. Sabyasachi Tarat and Pinaki Majumdar, *Pairing Fluctuations and Anomalous Transport Above the BCS-BEC Crossover in the Two Dimensional Attractive Hubbard Model*, arXiv:1105.1156.

Invited Lectures/Seminars:

1. *Distinguished Lecture Series: Quantum many body physics in terms of classical fields*, SNBNCBS Kolkata, Jan-Feb 2011.

2. *New approach to correlated electron systems*, JNCASR Bangalore, Feb 2011.

3. *The Hubbard model on optical lattices*, QIPA Meeting, HRI Allahabad, Feb 2011.

Other Activities:

1. Organised a workshop on Correlated Electron Systems at HRI in Oct 2010.
2. Organised an International School on Functional Materials at HRI in March-Apr 2011.
3. Co-organised and participated in the KVPY interviews at HRI in Jan 2011.
4. Co-ordinated JEST 2011 (along with T. Roy Choudhury (HRI) and R. Adhikari (IMSc)).

Biswarup Mukhopadhyaya

Research Summary:

Extensive investigations have been carried out on the possibility of new physics signals at the Large Hadron Collider (LHC), and on distinguishing among different theoretical scenarios using these signals. In particular, the importance of a novel and very promising signal, namely, same-sign trileptons, has been emphasized. It has been pointed out for the first time that such signals are detectable in the early run of the LHC for lepton-number violating scenarios such as R-parity violating supersymmetry.
(with Satyanarayan Mukhopadhyay)

The issue of distinguishing among various theoretical scenarios has been taken up in the special context of new signals with low missing transverse energy. Specific criteria have been developed for achieving distinction among R-parity violating supersymmetry, theories of universal extra dimensions and Little Higgs models with broken T-parity, all of which normally lead to similar signals.
(with Kirtiman Ghosh and Satyanarayan Mukhopadhyay)

A situation in supersymmetric theories has been investigated, where the origin of supersymmetry breaking is close above the TeV scale. A theoretical framework has been proposed, where modular fields associated with extra compact spacelike dimensions play a crucial role in this process. It has been demonstrated that such a situation, with harmless but highly consequential hard SUSY-breaking terms, can lead to a substantial upward revision of the upper bound of the lightest neutral Higgs mass.
(with Satyanarayan Mukhopadhyay and Soumitra SenGupta)

Publications:

1. Kirtiman Ghosh, Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, *Discrimination of low missing energy look-alikes at the LHC*, JHEP **1010**, 096, (2010)

2. Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, *Same-sign trileptons and four-leptons as signatures of new physics at the CERN Large Hadron Collider*, Phys. Rev **D82**, 031501, (2010)

3. Pradipta Ghosh, (IACS, Kolkata) , Paramita Dey, Biswarup Mukhopadhyaya, Sourov Roy, *Radiative contribution to neutrino masses and mixing in $\mu\nu$SSM*, JHEP **1005**, 087, (2010)

4. Nishita Desai, Biswarup Mukhopadhyaya, *R-parity violating resonant stop production at the Large Hadron Collider*, JHEP **1010**, 060, (2010)

5. Biswarup Mukhopadhyaya, Pran Nath *et al.*, *The Hunt for New Physics at the Large Hadron Collider*, Nucl. Phys. Proc. Suppl **200-202**, 185, (2010)

6. 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)

7. 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)

Preprints:

1. Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, Soumitra SenGupta, , *Low-scale SUSY breaking by modular fields and Higgs mass bounds* arXiv:1103.3678 [hep-ph]

Conference/Workshops Attended:

1. *Current Trends in High Energy Physics*, IIT, Mumbai, India, May, 2010.

2. *India-CMS Meeting*, NISER, Bhubaneswar, India, October, 2010.

3. *International Conference on Sustenability*, IIM, Shillong, India, December, 2010.

4. *Dark Matter in the LHC Era*, SINP, Kolkata, India, January, 2011.

5. *RECAPP Meeting on Experimental and Theoretical Issues at the LHC*, Visva-Bharati, Santiniketan, India, January, 2011.

6. *Current Trends in Nuclear and Particle Physics*, BHU, Varanasi, India, March, 2010.

7. *First Run of the LHC*, IACS, Kolkata, India, March, 2011.

Visits to other Institutes:

1. Indian Institute of Science Education and Research, Kolkata, April, 2010.
2. Physical Research Laboratory, Ahmedabad, India, April, 2010.
3. Indian Institute of Technology, Mumbai, India, May, 2010.
4. Banaras Hindu University, June, 2010 and March, 2011.
5. National Institute of Science Education and Research, Bhubaneswar, October, 2010.
6. Saha Institute of Nuclear Physics, Kolkata, January, 2011.
7. Visva-Bharati, Santiniketan, January, 2011.
8. Burdwan University, Burdwan, March, 2011.

Invited Lectures/Seminars:

1. *Two Lectures on Neutrino Physics*, IISER, Kolkata, April, 2010.
2. *Hunting After Roots: The Large Hadron Collider and New Physics*, Colloquium, PRL, Ahmedabad, April, 2010..
3. *New Physics, Newer Signals and the LHC*, Current Trends in High Energy Physics, IIT, Mumbai, May, 2010..
4. *Looking for What Everything is Made of*, Inspire Programme, Banaras Hindu University, Varanasi, June, 2010.
5. *The World of the Very Small: Searches and Symmetries*, Inspire Programme, Jadavpur University, Kolkata, July, 2010.
6. *Same Sign Trileptons at the LHC*, India-CMS Meeting, NISER, Bhubaneswar, October, 2010.
7. *A Boat Beneath a Sunny Sky: Sustaining Science Itself*, International Conference on Sustenability, Indian Institute of Management, Shillong, December, 2010.
8. *SUSY@7TeV: Some Recent Suggestions*, First Run of the LHC, IACS, Kolkata, March, 2011.

9. *The Higgs Boson and the LHC*, Current Trends in Nuclear and Particle Physics, BHU, Varanasi, March, 2011.

10. , The Wonder that is the Higgs Boson, Burdwan University, Burdwan, March, 2011.

Other Activities:

1. Taught a course on Quantum Mechanics 1, August-December, 2010.

2. Continued to serve as the Centre Co-ordinator, Regional Centre for Accelerator-based Particle Physics.

3. Served on the following committees of the institute: Physics Graduate Committee, Local Works Committee, Medical Advisory Committee (convener), Faculty Advisory Committee.

Satchitananda Naik

Research Summary:

Closed String Field theory

in Super Twistor Space and Maximal Supergravity Amplitudes A closed

string field theory action is formulated for the $N = 8$ 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. It is proposed that the closed string field theory four point amplitude will connect the self-dual with the anti-seldual part of the action so that one gets full Supergravity action starting from self-dual supergravity

Reprint:

1. Author: Satchidananda Naik, *Closed String Field Theory for Super Twistors and Maximal Supergravity ,* Progress of Theoretical Physics Supplement No 188 page 126 (2011)

Conference/Workshops Attended:

1. **String Field Theory 2011 , Kyoto Japan, 18th oct-22nd Oct. 2010**

2. **Workshop on non-perturbative aspects of quantum field theory, IACS, KOLKATA, Dec-20 ,2010**

3. **Inian String Meeting 2011, PURI,from 4th Jan-9th Jan 2011**

Visits to other Institutes:

1. **Yukawa Institute of Physics Kyoto Japan,from 17th-22nd oct,2010**

2. **IACS Kolkata, From 19th Dec–22nd Dec. 2010**

Invited Lectures/Seminars:

1. Closed String Field Theory for Super Twistors

   and Maximal Supergravity ,
   at SFT 2010, Kyoto, Japan

Courses Given:

1. **Advanced quantum field theory**

G. Venketeswara Pai

Research Summary:

I am working on two classes of problems. The first one involves understanding the role of strong Coulomb interactions on nanoscale inhomogeneities in transition metal oxides like manganites and studying their physical properties such as Hall conductivity and isotope effect. The second one deals with the effect of spin-orbit coupling in mesoscopic systems to generate tunable spin currents and non-Abelian Berry phases.

Preprints:

1. Sanjoy Datta, G. Venketeswara Pai, and T. P. Pareek, *Tunable Spin Filtering using a Quantum Wire Network,* in preparation.

Other Activities:

1. Guided a VSP project student, Somesh Chandra Ganguli (IIT-Kanpur) during May-June, 2010.
2. Guided the project of a second year graduate student, Sourabh Pradhan, during Aug-Dec 2010.
3. Taught a first year graduate course, Statistical Mechanics, during Jan-May 2010 (with Pinaki Majumdar).
4. Taught a second year graduate course, Condensed Matter Physics II, during Aug-Dec 2010 (with T. P. Pareek).
5. Organized a workshop on "Physics of Strong Correlation" at HRI during 12-14 Nov 2010 (with Pinaki Majumdar and Arghya Taraphder (IIT-Kharagpur)).
6. Organized an "International School and Conference on Functional Materials" at HRI during 28 March - 03 April, 2011 (with Pinaki Majumdar, Y. Sudhakar (SINP), and Peter Littlewood (Cambridge)).
7. Member of the KVPY interview panel at HRI, Jan 2011.
8. Member of the Physics PDF-visitors' committee and library committee.

Sudhakar Panda

Research Summary:

We studied the bounds on the tensor wave in a class of twisted inflation models where $D(2k+4)$-branes are wrapped on cycles in the compact manifold as well as the KK-direction in the corresponding effective field theory. While the lower bound was found to be similar to that in Type IIB models of brane inflation, the upper bound turns out to be significantly different for a range of values of the parameters satisfying the self-consistency relation and the observational data. We also observed that the wrapped $D8$-brane is the most attractive from cosmological prospective.

We reanalysed our earlier investigations of the brane-antibrane inflation in a warped deformed conifold background, where now we include the contributions to the inflation potential arising from imaginary anti-self-dual (IASD) fluxes including the term with irrational scaling dimension. The analysis revealed that these corrections to the effective potential help in relaxing the severe fine tunings associated with the earlier analysis. Required number of e-folds, observational constraint on COBE normalization and low value of the tensor to scalar ratio are achieved which are consistent with WMAP seven years data.

We showed how the Newton-Cartan formulation of Newtonian gravity can be obtained from gauging the Bargmann algebra, i.e., the centrally extended Galilean algebra. In this gauging procedure several curvature constraints are imposed. These convert the spatial (time) translational symmetries of the algebra into spatial (time) general coordinate transformations, and make the spin connection gauge fields dependent. In addition we require two independent Vielbein postulates for the temporal and spatial directions. In the final step we impose an additional curvature constraint to establish the connection with (on-shell) Newton-Cartan theory.

We constructed a model of quintessence in string theory based on the idea of axion monodromy. In the model, the quintessence field is an axion whose shift symmetry is broken by the presence of 5-branes which are placed in highly warped throats. This gives rise to a potential for the axion field which is slowly varying, even after incorporating the effects of moduli stabilization and supersymmetry breaking. We find that the resulting time dependence in the equation of state of Dark Energy is potentially detectable, depending on the initial conditions. The model has many very light extra particles which live in the highly warped throats, but these are hard to detect. A signal in the rotation of the CMB polarization can also

possibly arise.

Publications:

1. S. Panda, M. Sami and I. Thongkool, *Reheating the D-brane Universe via preheating,* Phys. Rev. **D 81**, 103506, (2010)

2. S. Panda, M. Sami and J. Ward, *Bounds on Tensor wave and Twisted Inflation,* Phys. Rev. **D 82**, 103511, (2010)

Preprints:

1. A. Ali, A. Deshamukhya, S. Panda and M. Sami, *Inflation with improved D3-brane potential and the fine tuning associated with the model,* arXiv: 1010.1407 [hep-th] (to appear in Euro. Phys. Jour. C)

2. R. Andringa, E. Bergshoeff, S. Panda and M. de Roo, *Newtonian Gravity and the Bargman Algebra,* arXiv: 1011.1145 [hep-th] (to appear in Class. Quant. Grav.)

3. S. Panda, Y. Sumitomo and S. P. Trivedi, *Axions as Quintessence in String Theory,* arXiv: 1011.5877 [hep-th] (to appear in Phys. Rev. D)

Conference/Workshops Attended:

1. *SERC Th. Review Meeting*, India, April 2010.

2. *PFNG Meeting on Cosmology*, India, December 2010.

3. *ISM11*, India, January 2011.

4. *Winter School on Gravity and Cosmology*, India, February 2011.

5. *Indo-Japanese Workshop on Comology*, India, February 201.

6. *HEP Conference*, India, February 2011.

Visits to other Institutes:

1. University of Groningen, Groningen, The Netherlands, September 2010,

2. Assam University, Silchar, India, November 2010,

3. University of Canterbury, Christchurch, New Zealanad, March 2011.

Invited Lectures/Seminars:

1. *Brane Inflation and Reheating*, SERC Rev. Meeting, IIT Mumbai, Mumbai, April 2010.
2. *Inflation and Quitessence in String Theory*, ISM-11, DAE Institutes of India, Puri, January 2010.
3. *Inflation, Reheating and Quintessence*, Indo-Japanese Workshop on Cosmologgy, Delhi, February 2011.
4. *Inflation and Quintessence in String Theory*, HEP Conference, IIT Kanpur, Kanpur February 2011.
5. *Lectures on String Theory*, Erskine Lectures, University of Canterbury, Christchurch, March 2011.

Academic recognition/Awards:

- Elected as Fellow, NASI, India, 2010,
- Recipient of Erskine Fellowship from Univ. of Canterbury, New Zealand, 2011.

Other Activities:

1. Dean, Administration, from May, 2009.
2. Member, Local Works Committee, from September, 2010.
3. Member, Faculty Advisory Committee, from September, 2010.
4. Member, Hortculture Committee, from September, 2010.
5. Member, Board of Studies, CTP, Jamia Univ, Delhi. 2010.
6. Orgamizer, PFNG Meeting, December 2010.
7. Member, Scientific Advisory Committee, HEP Conf at IIT Kanpur, February 2010.
8. Thesis Examiner of a Student of IMSC, February 2010.
9. Referee of Research articles for JHEP and Phys. Rev. D 2010-11.

Tribhuvan Prasad Pareek

Research Summary:

We have focused on the Anamolous Hall effect and Spin Hall effect. Though the research histrories of two are rather different. However in recent years there is growing appreciation that these two phenomena are close cousin. The earlier one is related to charge transport and the later one is associated spin accumulation. The very exsitence of these two phenomena requires the presence spin-orbit scattering which plays an important role. In past year we have concentrated on this and have some preliminary resluts. Beside this we have also studied spin analogue of optical double refreaction phenomena in lithographic structures and its relation to spin accumulation at sample edge. Building on the above ideas we have continued exploring "Quantum Coherent Charge and Spin Transport".We have devloped a scattering theory with the use of spin-coherent states. Using this we are able to formulate spin-current-conservation and charge current conservation on equal footing.

Preprints:

1. *Shishir k. Pandey and T. P. Pareek, Spin accumultaion due to double refraction at lithographic boundaries, manuscript under prepration*
2. *T. P. Pareek, Exact T-Matrix operator for spin-orbit scattering based on generic symmetry consideration and its relevance for Anamolous and Spin Hall effect, manuscript under preparation*
3. *T.P. Pareek, Quantum coherent Charge and Spin Transport, manuscript under preparation*

Visits to other Institutes:

1. IOP, Bhubaneswar, India, July 2010.

Invited Lectures/Seminars:

1. *Spin transport in nano-systems*, NISER, Bhubaneswar, July 2010

Other Activities:

1. I have taught Advanced cond mat course in our graduate programme. I am member of 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.

Arun Kumar Pati

Research Summary:

I have joined Quantum Information and Computation (QIC) group at HRI in January 2011. My research areas are quantum information theory, general quantum theory and fundamental aspects of quantum mechanics. Current research topics include investigating quantum correlations in multipartite quantum systems, role of entanglement and correlations in quantum algorithms, study of quantum dynamical maps which are not-completely positive, information processing in the presence of closed time-like curves and related issues.

Since I joined here we (myself and other memebers of QIC group) have been involved in trying to understand more deeply the differences between classical and quantum information in connection with the no-hiding theorem. This says that if information stored in an arbitrary state disappears from one system it moves to another part of Hilbert space with no information being hidden in the correlation. Recently, the no-hiding theorem has also been experimentally tested. It may be mentioned that this is first direct experimental test of conservation of quantum information. In our ongoing work we are trying to establish what class of quantum states can be hidden in the correlations. We believe that this will have important bearing in quantum communication.

Publications:

1. J. R. Samal, A. K. Pati, and Anil Kumar, *Experimental Test of the Quantum No-Hiding Theorem,* Phys. Rev. Lett. **106**, 080401 (2011)

Conference/Workshops Attended:

1. *Silver Jubilee Symposium: 75 Years of Quantum Entanglement Foundations and Information Theoretic Application, held at S N Bose Center, Kolkata*, India, January, 2011.

Invited Lectures/Seminars:

1. *Quantum States, Entanglement and Closed Time Like Curves*, 75 Years of Quantum Entanglement at SS N Bose Center, Kolkata, January, 2011.

Other Activities:

1. Co-organizer of International School and Conference of Quantum Information Processon and Applications (QIPA) held at HRI, Allahabad during Feb 14-20, 2011.

2. Panelist and expert member for a discussion on Quantum Verification and Validation (Quantum V&V) in New Delhi being organized by Lockheed Martin (USA) in association with the India-US Science and Technology Forum (IUSSTF).

3. Acted as an expert for the evaluation of Ph.D work of Mr. Manoj k. Mishra (working under Prof. H. Prakash) for upgaradation of his UGC NET JRF in Physics Depratment, University of Allahabad.

4. Referee for national and International journals.

Sumathi Rao

Research Summary:

During the period, April 2010 - March 2011, I worked in the areas of graphene and a new class of insulators called topological insulators. I worked on transport through junctions of superconductors and graphene and charge pumping through such structures. I also studied the unusual properties of the edge states of topological insulators and studied charge and spin fractionalisation of the elementary excitations in such edge states.

We considered the phenomenon of quantum charge pumping of electrons across a superconducting double barrier structure in graphene in the adiabatic limit. In this geometry, quantum charge pumping could be achieved by modulating the amplitudes (Δ_1 and Δ_2) of the gaps associated with the two superconducting strips. We showed that the superconducting gaps give rise to a transmission resonance in the Δ_1-Δ_2 plane, resulting in a large value of pumped charge, when the pumping contour encloses the resonance. This was in sharp contrast to the case of charge pumping in a normal double barrier structure in graphene, where the pumped charge was very small, due to Klein tunneling. We analysed the behaviour of the pumped charge through the superconducting double barrier geometry as a function of the pumping strength and the phase difference between the two pumping parameters, for various angles of the incident electron.

We proposed a three terminal spin polarized scanning tunneling microscope setup for probing the helical nature of the Luttinger liquid edge state that appears in the quantum spin Hall system. We showed that the three-terminal tunneling conductance strongly depends on the angle (θ) between the magnetization direction of the tip and the local orientation of the electron spin on the edge while the two terminal conductance is independent of this angle. We demonstrated that chiral injection of an electron into the helical Luttinger liquid (which occurs when θ is zero or π) is associated with fractionalization of the spin of the injected electron in addition to the fractionalization of its charge. We also pointed out a spin current amplification effect induced by the spin fractionalization.

We are currently studying spin currents in helical Luttinger liquid wires in the presence of a local magnetic field, when the local magnetic field is applied to the edge via the polarised tip of a scanning tunneling microscope. We are also studying transport through 'bent' edges of topological insulators, where there is unusual transport because of the change in helicity of the helical Luttinger liquid at the corner where the bend occurs.

Publications:

1. Arijit Kundu, Sumathi Rao and Arijit Saha, *Resonant tunneling through superconducting double barrier structures in graphene*, Phys. Rev. **B82**, 155441 (2010).

2. Arijit Kundu, Sumathi Rao and Arijit Saha, *Quantum charge pumping through a superconducting double barrier structure in graphene*, Phys. Rev. **B83**, 165451 (2011).

3. Sourin Das and Sumathi Rao, *Spin polarised scanning tunneling probe for helical Luttinger liquids*, Phys. Rev. Lett. **106**, 236403 (2011).

Preprints:

1. A. Agrawal, Sourin Das and Sumathi Rao, *Spin currents in helical Luttinger liquid wires in the presence of a local magnetic field*

2. Mohana Rao Barri and Sumathi Rao, *Transport through bent helical edge states of a quantum spin Hall system*

Conferences/Workshops attended:

1. Quantum matter in low dimensions : Opportunities and challenges, 6-10 September 2010, Nordita, Stockholm, Sweden

2. ICTS Discussion meeting and Chandrasekhar lectures, 6-8 December 2010, Indian Institute of Bangalore, India

3. ICTS condensed matter conference 2010, 12-23 December 2010, Infosys campus, Mysore, India

4. New trends in field theories, 7-12 February 2011, BHU, Varanasi, India

5. The international school and conference on quantum information processing and applications, 14-20 Feb 2011, Allahabad

Visits to other Institutes:

1. On sabbatical at LPTHE and LPTMC, University of Paris, Jussieu, Sept 15, 2009 - Sept 15, 2010

2. Forschungszentrum, Juelich, Germany, week in April 2010

3. Perimeter institute for Theoretical Physics, Waterloo, Canada, June, 2010

4. CHEP, Indian Institute of Science, Bangalore, November end - December 2010

Invited Lectures/Seminars:

1. *Transport through junctions of quantum wires*, Department of Physics, University of Paris, Orsay, 20 May 2010

2. Colloquium on *Graphene : Nobel Prize 2010*, October 2010, HRI, Allahabad

3. *Spin polarised scanning tunneling microscopy of helical Luttinger liquids*, ICTS conference on condensed matter physics, Infosys campus, Mysore 2010

4. *Topological insulators and helical edge states*, New trends in field theories, BHU, Varanasi, Feb 2011

5. *Introduction to topological insulators*, School on quantum computation, HRI, Allahabad, Feb 2011

6. Graphene, popular talk, Ramakrishna Mission, Allahabad, March 2011

Other Activities:

1. Taught *Statistical mechanics* , Jan-May 2011.

2. Convenor, Local works committee

3. Convenor, Women's grievance cell

4. Member, Faculty Advisory committee

5. Member, Board of Studies, School of Physics, Jawaharlal Nehru University, New Delhi

V. Ravindran

Research Summary:

Higher order QCD radiative corrections play important role in most of the physics studies at Tevatron and Large Hadron Collider (LHC). During 2010-2011, we have obtained next to leading order QCD predictions for the associated production of vector boson (Z/W) with the Kaluza-Klein modes of the graviton in large extra dimensional model at the LHC, and a complete next to next to leading order QCD corrections to the resonant sneutrino and charged slepton production cross sections at hadronic colliders such as the Tevatron and the Large Hadron Collider within the context of R-parity violating supersymmetric model. We have obtained various kinematic distributions using a Monte Carlo code which is based on the two cut off phase space slicing method that handles soft and collinear singularities appearing at NLO level. In the case of sneutrino and charged slepton productions, we have obtained fully analytical NNLO result for the total cross section. We have estimated the impact of the QCD corrections on various observables and found that they are significant. We also have shown the reduction in factorization scale uncertainty when QCD corrections are included.

Publications:

1. M. C. Kumar, Prakash Mathews, V. Ravindran, Satyajit Seth, *Vector boson production in association with KK modes of the ADD model to NLO in QCD at LHC* J.Phys. **G38** 055001,(2011).

2. V. Ravindran, *Soft and collinear gluon corrections to Higgs production beyond two loop*, PoS RADCOR2009, **039** ,2010.

3. Swapan Majhi, Prakash Mathews, V. Ravindran, *NNLO QCD corrections to the resonant sneutrino/slepton production at Hadron Colliders.* Nucl.Phys.**B850**,287,(2011)

4. M.C. Kumar, Prakash Mathews,V. Ravindran, Satyajit Seth, *Graviton plus vector boson production to NLO in QCD at the LHC.* Nucl.Phys. **B847**, 54,(2011).

Conference/Workshops Attended:

1. *SERC review meeting*, IIT Mumbai, May 21-22, 2010

2. *India-CMS Meeting*, NISER , IOP Campus, Bhubaneswar , 28th - 30th October 2010

3. *The Workshop on Synergy between High Energy and High Luminosity Frontiers*, TIFR, Mumbai, January 10-12, 2011

4. LHC discussion meeting, Santiniketan, January 27-30, 2011

Invited Lectures/Seminars:

1. *QCD results for Higgs production at LHC*, SERC review meeting, IIT Mumbai, May 21-22, 2010.

2. *Higgs Production at Colliders*, The Workshop on Synergy between High Energy and High Luminosity Frontiers, TIFR, Mumbai, January 10-12, 2011.

3. *Higher Order QCD corrections to Higgs Production at the LHC*, LHC discussion meeting, Santiniketan, January 27-30, 2011.

Amitava Raychaudhuri

Research Summary:

In 2010-11 research has been concentrated on neutrino mass models, leptogenesis, and grand unified theories.

Small non-zero neutrino masses, as observed in Nature, suggest new directions for extension of the Standard Model. A natural way to achieve light neutrino masses is through the seesaw mechanism where the heaviness of another state – a singlet neutrino – is tied to the lightness of the observed neutrinos. A model based on the SO(10) grand unified theory has been proposed which uses an extra singlet fermion and a 16-plet Higgs field besides the usual fermions of three generations and Higgs in the 10 and 120 representations to achieve light neutrinos through a multistep seesaw. The model results in tribimaximal mixing – a close approximation to the observations – and is consistent with gauge coupling unification.

Lepton number violation and CP-violation in the decay of a heavy neutrino has been suggested as a means to accomplish a lepton-antilepton asymmetry in the universe. This can be subsequently converted to a baryon asymmetry through non-perturbative sphaleron effects. In a grand unified SO(10) model with a singlet neutrino it has been shown that leptogenesis and small neutrino masses can both be accommodated. It is nontrivial because grand unification restricts the energy scales and the neutrino Dirac masses are related to the up-type quark masses. It has been shown that the model is perfectly consistent with proton decay limits.

In a three-generation neutrino mass model based on the Type-1 seesaw mechanism, what is the condition that yields three *exactly* massless neutrinos? This issue has been addressed and it has been shown that some of the options follow when a symmetry is imposed on the Lagrangian. Furthermore, when the symmetry is softly broken the neutrinos pick up masses, in this model, at the two-loop level. Since the effect occurs in higher order in perturbation theory, the mass of the heavy members of the seesaw can be as light as a TeV, which may be testable at the LHC.

In the absence of a full theory of quantum gravity it is hoped that some of its features may 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 in-

termediate scales which may be detectable through neutron-antineutron oscillations or even through the production of new gauge bosons. All possible operators of this class for SO(10) and E(6) GUTs have been considered and their effect on gauge coupling unification examined.

Publications:

1. Mina K. Parida and Amitava Raychaudhuri, *Inverse see-saw, leptogenesis, observable proton decay and* $\Delta_{\rm R}^{\pm\pm}$ *in SUSY SO(10) with heavy* W_R, Phys. Rev. **D82,** 093017 (2010).

2. Joydeep Chakrabortty, Srubabati Goswami and Amitava Raychaudhuri, *An SO(10) model with adjoint fermions for double seesaw neutrino masses*, Phys. Lett. **B698** 265-270 (2011).

Preprints:

1. Rathin Adhikari and Amitava Raychaudhuri, *Light neutrinos from massless texture and below TeV seesaw scale,* arXiv:1004.5111 [hep-ph].

2. Joydeep Chakrabortty and Amitava Raychaudhuri, *Dimension-5 operators and the unification condition in SO(10) and E(6),* arXiv:1006.1252 [hep-ph].

Conference/Workshops Attended:

1. *INO 2010 meeting*, IIT Kharagpur, Kharagpur, May 2010.

2. *Indian Physics: Research at the Frontiers, Meeting preceding IUPAP Meeting in New Delhi*, INSA, New Delhi, November 2010.

3. *National Conference on Particle Physics and Cosmology*, Department of Physics, University of Burdwan, March 2011.

Invited Lectures/Seminars:

1. *A tool for probing the building blocks of Nature: Neutrino Novelties*, Evening lecture, INO 2010 meeting, IIT Kharagpur, May 2010.

2. *High Energy Physics*, Indian Physics: Research at the Frontiers, INSA, New Delhi, November 2010.

3. *Light neutrinos from massless texture and below TeV seesaw scale*, Theoretical Physics Seminar, Physical Research Laboratory, Ahmedabad, November 2010.

4. *A passage to India: Exploring neutrinos from the far corers of the earth at INO*, Institute Colloquium, Physical Research Laboratory, Ahmedabad, November 2010.

5. *The trends of evolution of particle physics and its interface with cosmology*, Keynote address, National Conference on Particle Physics and Cosmology, Department of Physics, University of Burdwan, March 2011.

Ashoke Sen

Research Summary:

My research during the period April 2010 - March 2011 focussed mainly on understanding black hole entropy in string theory. The main results include computation of logarithmic corrections to a set of extremal black hole entropy, prediction of the sign of the index from the analysis of near horizon geometry and a detailed analysis of wall crossing formula in $N = 2$ supersymmetric string theories. To whatever extent it has been tested, the macroscopic results on black hole entropy and index computed from the near horizon geometry always agree with the microscopic results.

Publications:

1. J. Manschot, B. Pioline, A. Sen, "A Fixed point formula for the index of multi-centered N=2 black holes," JHEP **1105**, 057 (2011). [arXiv:1103.1887 [hep-th]].

2. A. Sen, "State Operator Correspondence and Entanglement in AdS_2/CFT_1," [arXiv:1101.4254 [hep-th]].

3. J. Manschot, B. Pioline, A. Sen, "Wall Crossing from Boltzmann Black Hole Halos," [arXiv:1011.1258 [hep-th]].

4. A. Dabholkar, J. Gomes, S. Murthy, A. Sen, "Supersymmetric Index from Black Hole Entropy," JHEP **1104**, 034 (2011). [arXiv:1009.3226 [hep-th]].

5. A. Sen, "How Do Black Holes Predict the Sign of the Fourier Coefficients of Siegel Modular Forms?," [arXiv:1008.4209 [hep-th]].

6. I. Mandal, A. Sen, "Black Hole Microstate Counting and its Macroscopic Counterpart," Class. Quant. Grav. **27**, 214003 (2010). [arXiv:1008.3801 [hep-th]].

7. S. Banerjee, R. K. Gupta, A. Sen, "Logarithmic Corrections to Extremal Black Hole Entropy from Quantum Entropy Function," JHEP **1103**, 147 (2011). [arXiv:1005.3044 [hep-th]].

Invited Lectures/Seminars at Schools/Conferences:

1. Solvay Workshop on Symmetries and dualities in gravitational theories, Brussels, May 19-21, 2010
2. 40th International Symposium Ahrenshoop on the Theory of Elementary Particles, Berlin August 23 - 27, 2010.
3. String Theory: Formal Developments and Applications, Cargese, June 21 - July 3, 2010
4. ICHEP 2010, Paris, July 22 to July 28, 2010.
5. Advanced String School, Puri, Oct 4-10, 2010
6. Insa meeting, December 2010
7. Indian Strings meeting, Puri, January 2011
8. SERC school on High Energy Physics, Delhi, Jan-Feb, 2011
9. School on Modular Morms, ICTP, Trieste, February-March, 2011

Courses Given:

1. Black hole thermodynamics, February-April, 2011 (at LPTHE, Paris with Atish Dabholkar)
2. Quantum Field Theory 1, January-May, 2011 (at HRI)

Prasenjit Sen

Research Summary:

The major activity this year was electronic structure calculation of atomic clusters. We studied pure 4d and mixed 3d-4d bimetallic transition metal (TM) clusters. In particular, we studied Rh_mCo_n clusters for $m = 1-5$ and $n = 1-2$, and Rh_n clusters for $n = 1-9$. This work was done in collaboration with the experimental group of Prof. Kit Bowen of the Johns Hopkins University, USA. Our theoretical calculations explained the negative ion photoelectron spectrum they measured, and gave information about the ground state structures of these clusters. In addition, we studied 3d TM doped Ge clusters and tried to understand how far the electron counting rules explain their relative stability. We revealed that the electronic structure of these clusters are more complex than it was previously believed. In some clusters there is an indication of a free electron gas formation. In others there are is no such indication. Therefore, it is difficult to interpret their stability by blindly using the electron counting rules. We also started studies of alkaline earth clusters doped with 3d transition metal atoms in search of new magnetic superatoms.

Clusters deposited on substrates is a scientifically and technologically important area of research. There have been a number of experimental studies on such systems. However, till date, our theoretical understanding of such systems is only rudimentary. We have initiated a systematic study of surface supported clusters. For this, we are developing a series of theoretical tools.

Publications:

1. 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,* J Phys. Chem. C **112**, 19963, (2010)

2. A. Nandy, P. Mahadevan, P. Sen and D. D. Sharma, *KO_2: Realization of orbital ordering in a p-orbital system,* Phys. Rev. Lett. **105**, 056403, (2010)

3. D. Bandyopadhyay, P. Kaur and P. Sen, *New Insights into Applicability of Electron-Counting Rules in Transition Metal Encapsulating Ge Cage Clusters,* J Phys. Chem. A **114**, 12986, (2010)

4. H. Wang, Y. J. Ko, L. G. Garcia, P. Sen, M. R. Beltran and K. H. Bowen, *Joint photoelectron and theoretical study of* $(Rh_mCo_n)^-$ $(m = 15, n = 12)$ *cluster anions and their neutral counterparts* Phys. Chem. Chem. Phys. **13**, 7685, (2011)

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

Preprints:

1. V. M. Medel, J. U. Reveles, S. N. Khanna, V. Chouhan, P. Sen and A. W. Castleman Jr, *Hunds Rule in Superatoms with Transition Metal Impurities* (in preparation).

2. H. Wang, Y. J. Ko, K. Bowen, M. Beltran, F. Buendia, V. Chouhan and P. Sen, *Electronic, magnetic and structural properties of* R_n *(n=1-9) clusters: Joint negative ion photoelectron and density ab initio studies,* (in preparation).

Conference/Workshops Attended:

1. *Theory of Atomic and Molecular Clusters-VI*, Mexico, June 2010.

Visits to other Institutes:

1. Virginia Commonwealth University, Richmond VA, USA, June-July 2010.

Invited Lectures/Seminars:

1. *Designing Magnetic Superatoms with Novel Properties*, Theory of Atomic and Molecular Clusters-VI, UNAM, Mexico City, Mexico, June 2010.

Other Activities:

1. Reviewed manuscripts for the journals *Physical Review B* and *Applied Physics Letters*.
2. Acted as the nodal person at HRI for the Garuda Grid throughout the year.
3. Taught a course on Atomic and Molecular Physics.
4. Mentored visiting undergraduate (VSP), graduate students and post-docs.

Ujjwal Sen

Research Summary:

In the last year, I have been working mainly at the interface between many-body physics and quantum information. Additionally, I have also co-written a broad-audience invited review on the utility of quantum laws in communication channels in Physics News.

At the interface of many-body physics and quantum information, we showed that parallel to but different from the cluster mean field approach to dealing with analytically intractable many-body systems, there exists a cluster entanglement mean field theory, which provides better results for the onset of phase transitions in such systems. In another work, we showed that an empirical law of numbers, called the Benford's law, appearing in nature and mathematics, can be used to predict cooperative quantum phenomena. Other works included a theory of atom counting in expanding ultracold clouds and of fermions and spins in strongly correlated systems, an observation that the behavior of quantum discord – an information-theoretic measure of quantum correlations – can predict the behavior of entanglement in quantum spin systems, and that ergodic quantum correlations can originate from nonergodic classical correlations and magnetizations.

Publications:

1. Aditi Sen(De) and Ujjwal Sen, *Quantum Advantage in Communication Networks*, Physics News **40**, 17 (2010).

2. Sibylle Braungardt, Mirta Rodríguez, Aditi Sen(De), Ujjwal Sen, Roy J. Glauber, and Maciej Lewenstein, *Counting of fermions and spins in strongly correlated systems in and out of thermal equilibrium*, Phys. Rev. A **83**, 013601 (2011).

Preprints:

1. Aditi Sen(De) and Ujjwal Sen, *Cluster Entanglement Mean Field inspired approach to Criticality in Classical Systems*, arXiv:1008.0965.

2. Himadri Shekhar Dhar, Rupamanjari Ghosh, Aditi Sen(De), and Ujjwal Sen, *Quantum Discord Surge Heralds Entanglement Revival in an Infinite Spin Chain*, arXiv:1011.5309.

3. Sibylle Braungardt, Mirta Rodríguez, Aditi Sen(De), Ujjwal Sen, and Maciej Lewenstein, *Atom Counting in Expanding Ultracold Clouds*, arXiv:1103.1868.

4. R. Prabhu, Aditi Sen(De), Ujjwal Sen, *Ergodicity from Nonergodicity in Quantum Correlations of Low-dimensional Spin Systems*, arXiv:1103.3836.

5. Aditi Sen(De) and Ujjwal Sen, *Benford's Law: Detection of Quantum Phase Transitions similarly as Earthquakes*, arXiv:1103.5398.

Conference/Workshops Attended:

1. *Workshop on Quantum Chaos and Quantum Information*, Chennai, India, July 2010.

2. *International School and Conference on Quantum Information Processing and Applications (QIPA-2011)*, Allahabad, India, February 2011.

Invited Lectures/Seminars:

1. *Frustration in Quantum Spin Models and a quantum information perspective*, Invited seminar, Korea Institute for Advanced Study (KIAS), Seoul, South Korea, June 2010.

2. *Frustration in quantum spin models: A quantum information perspective*, Invited talk in the Workshop on Quantum Chaos and Quantum Information, Indian Instituite of Technology Madras, Chennai, India, July 2010.

Visits to other Institutes:

1. Korea Institute for Advanced Study (KIAS), Seoul, South Korea, June-July 2010.

2. School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India, July 2010.

3. Bose Institute, Kolkata, India, December 2010.

4. Indian Association for the Cultivation of Science, Kolkata, India, December 2010.

Other Activities:

1. Guided projects of a second-year HRI graduate student, Saurabh Pradhan, entitled "Capacities of Disordered Spin Chains employed as Quantum Channels" during Aug-Dec 2010, a first-year HRI graduate student, Abhishek Joshi, entitled "Nonlocality Boxes" during Jan-May 2011, and a first year HRI post-MSc student, Utkarsh Mishra, entitled "Quantum Cloning" during the latter period.

2. Organized the "International School and Conference on Quantum Information Processing and Applications (QIPA-2011)" held at HRI in February 2011. The other organizers were Arun K. Pati, Prabhu R., and Aditi Sen(De), of HRI. [www.hri.res.in/~qipa11/]

3. Guided project works of two students, Ameya Rane and Sudipto Singha Roy, under the visiting students programme (VSP) of HRI during May-June 2010.

4. Member of HBNI Cell, Talent Search Committee, and the Computer Committee at HRI.

5. Served as referees in national and international journals.

Ram Lal Awasthi

Research Summary:

SU(5) is the minimal extension of Standard Model(SM) towards unification, though it doesn't unify the gauge interaction so failed to be a consistent Grand Unified Theory(GUT). Though Supersymmetric(SUSY) extension of this model does unify, does not have space for neutrino masses. To explain neutrino masses we need to extend this minimal model. We have proposed SUSY symmetrised adjoint SU(5) which gives neutrino masses via Type-I+II+III seesaw mechanism. This model also predicts the scalar triplet to be possibly in the TeV scale, testable at LHC.
In supersymmetric theories the problem of having more multiplets in a consistent model to explain the neutrino masses is that beyond GUT scale gauge coupling of GUTs evolve and hit the landau pole before reaching Plank scale. It can possibly be cured by embedding gravitational effect (anyway to be added to have a complete theory) in a model based on any gauge group (Work in progress).
Reliable values of quarks and leptons are needed for model building at the fundamental scales. Using the data available at low energy scale we try to explain the physics at new scale, like Grand Unification scale. We are developing the Renormalization group evolution suited to our model (Work in progress).

Preprints:

1. Ram Lal Awasthi, Sandhya Choubey, Manimala Mitra (*arXiv:1009.0509*)

Conference/Workshop/School Attended:

1. *Nu-Horizones IV*, HRI-Allahabad, India, Feb 23-25, 2011
2. *Summer school on particle physics*, ICTP-Trieste, Italy, June 06-17, 2011

Atri Bhattacharya

Research Summary:

I have been working on several aspects of neutrino physics over the past year, including an attempt toward detecting exotic physics from neutrino events at ultra-high energy detectors like the IceCube, a project on pinning down the mass hierarchy of neutrinos using long baseline neutrino detectors and a project in collaboration with Satyanarayan Mukhopadhyay on leptogenesis. All of these projects are currently work-in-progress under the supervision of Prof. Raj Gandhi, and we expect to finish and submit our work on the preprint server over the next couple of months.

Conference/Workshops Attended:

1. *Workshop on Dark Matter in the LHC Era: Direct and Indirect Searches, Saha Institute of Nuclear Physics, Kolkata*, India, January, 2011

2. *NuFact 2010, Tata Institute of Fundamental Research, Mumbai*, India, October, 2010

Visits to other Institutes:

1. Physical Research Laboratory, Ahmedabad, India, October, 2010

Sanjoy Biswas

Research Summary:

I am working on collider aspects of supersymmetric extension of the Standard Model Physics in the context of the CERN Large Hadron Collider (LHC). My recent work based on finding new physics at the LHC in channels comprising prompt and delayed photons in a supersymmetric scenario in which the gravitino is the lightest supersymmetric particle and the lightest neutralino is the next- to-lightest supersymmetric particle. In addition, we assume that the second lightest neutralino and the lightest neutralino are nearly degenerate in masses and this leads to a prompt radiative decay of the former into a photon and a lightest neutralino with a large branching ratio. Such degenerate neutralinos can be realised in various representations of the SU(5), SO(10), and E(6) Grand Unified Theories. We have performed a detailed collider simulation of the multi-photon signals in association with jets and missing transverse energy in this scenario.

I have also worked on the aspects of supersymmetric theories with non-universal Higgs masses in the context of the LHC. We have suggested two methods to identify non-universal Higgs mass scenario with the help of tau-polarisation and charge asymmetry in the jet-lepton invariant mass distributions.

At present, I am working on the aspects of supersymmetric theories with Dirac gauginos.

Publications:

1. Sanjoy Biswas, Joydeep Chakrabortty and Sourov Roy, *Multi-photon signal in supersymmetry comprising non-pointing photon(s) at the LHC*, Phys. Rev. D **83**, 075009, (2011).

Preprints:

1. Subhaditya Bhattacharya, Sanjoy Biswas, Biswarup Mukhopadhyaya and Mihoko M. Nojiri, *Signatures of supersymmetry with non-universal Higgs mass at the Large Hadron Collider*, arXiv:1105.3097 [hep-ph].

Conference/Workshops Attended:

1. *Dark Matter in the LHC Era: Direct and Indirect Searches*, Saha Institute

of Nuclear Physics, Kolkata, INDIA, 4-8 January, 2011.

Visits to other Institutes:

1. Indian Association for the Cultivation of Science, Kolkata, India, 6th December to 10th December, 2011.

2. Department of Physics, University of California, Davis, USA, 27th October to 28th October, 2010.

3. Department of Physics, Oklahoma State University, Oklahoma, USA, 12th October to 27th October, 2010.

4. Theory Group, SLAC National Accelerator Laboratory, California, USA, 6th October to 12th October, 2010.

5. Department of theoretical physics, Institute for the Physics and Mathematics of the Universe, University of Tokyo, Kashiwa, Japan, 7th September to 6th October, 2010.

6. KEK Theory Center, Tsukuba, Japan, 25th August to 6th September, 2010.

Invited Lectures/Seminars:

1. *Right-handed sneutrino dark matter and its collider implications*, Invited talk in the Workshop on "Dark Matter in the LHC Era: Direct and Indirect Searches", Saha Institute of Nuclear Physics, Kolkata, India, 8th January, 2011.

2. *Sparticle mass reconstruction in supersymmetry with long-lived staus*, High-Energy Physics Seminar, Department of Physics, University of California, Davis, USA, 27th October, 2010.

3. *Sparticle mass reconstruction in supersymmetry with long-lived staus*, High-Energy Physics Seminar, Department of Physics, Oklahoma State University, Oklahoma, USA, 14th October, 2010.

4. *Sparticle mass reconstruction in supersymmetry with long-lived staus*, High-Energy Physics Seminar, Theory Group, SLAC National Accelerator Laboratory, California, USA, 8th October, 2010.

5. *Sparticle mass reconstruction in supersymmetry with long-lived staus*, High-Energy Physics Seminar, KEK Theory Center, Tsukuba, Japan, 30th August, 2010.

Other Activities:

1. I have been the tutor of the Quantum Field Theory course for the semester January- May, 2011.

Vikas Chauhan

Research Summary:

Superatoms are clusters of atoms characterized by electronic and chemical properties that are approximate to that of an atom in the periodic table from electronic and chemical point of view. Al_{13}^{-} is one of the famous example. However these superatoms do not have any magnetic moment. Recently first-principle studied on TM doped alkali cluster reveals new class of superatom which has magnetic moment also. In this year we studied TM doped alkaline earth metal cluster for searching of magnetic superatom. Theoretical studies on TM doped magnesium cluster shows interesting observation where observed magnetic moment can be understood in terms of Hund's rule even though wavefunctions delocalized over whole volume of cluster. Beside this important fact we also observed that stability of these clusters also enhanced by crystal field effect. Further we carried our calculation to transition metal doped calcium clusters. There we found an another intersting observation "interplay of crystal-field effect and Hund's rule" which played important role to determine the ground state of doped cluster.

Publications:

1. Victor M. Medel, Jose Ulises Reveles, Shiv N. Khanna, Vikas Chauhan, Prasenjit Sen, and A.Welford Castleman, *Hund's rule in Superatoms with transition metal impurities,* PNAS, **Vol.128**, 10062, (2011)

Preprints:

1. Vikas Chauhan, Prasenjit Sen and S.N. Khanna, *Interplay of crystal-field effects and Hund's coupling in supershells* (in preparation)

Conference/Workshops Attended:

1. *Workshop on Physics of Strong Correlation at H.R.I.*, India, 12-14 November 2011

Other Activities:

1. As tutor for Atomic and Molecular physics, 3 Jan - 6 May, 2011.

Nishita Dattatray Desai

Research Summary:

CP violating HWW couplings at the LHC: This work was done with Prof. Biswarup Mukhopadhyaya and Prof. Dilip Ghosh. We investigate the possibility of probing an anomalous CP-violating coupling in the HWW vertex at the LHC. Several kinematical distributions and asymmetries that can be used to ascertain the presence of a non-zero anomalous coupling are presented. We find that, for Higgs mass in the range 130-150 GeV and anomalous couplings allowed by the Tevatron data, these distributions can be studied with an integrated luminosity of 30-50 fb^{-1} at the 14 TeV run. Attention is specifically drawn to some asymmetries that enable one to probe the real and imaginary parts (as well as their signs) of the anomalous coupling, in a complementary manner. We also explicitly demonstrate that showering and hadronisation do not affect the utility of these variables, thus affirming the validity of parton level.

SUSY in Pythia8: I was awarded a studentship of four months to work on the event generation program Pythia. I spent the months August to November at CERN, Geneva working with Dr. Peter Skands on implementation of Supersymmetric processes in Pythia version 8. This includes implementation of squark and gaugino production along with two body decays of all sparticles. In particlar, we have implemented the case of single sparticle production in the case of R-parity violation taking into account the change in colour flow and including the modifications to showering and hadronisation. The preliminary release of this work is now available as Pythia v8.150.

Publications:

1. Nishita Desai and Biswarup Mukhopadhyaya, *R-parity violating resonant stop production at the Large Hadron Collider,* Journal of High Energy Physics **1010**, 060, (2010)

Preprints:

1. Nishita Desai, Dilip Kumar Ghosh, Biswarup Mukhopadhyaya, *CP-violating HWW couplings at the Large Hadron Collider.* arXiv:1104.3327 [hep-ph]

Conference/Workshops Attended:

1. *PSI Summer School, "Gearing up for LHC Physics"*, Switzerland, August 2010.
2. *Conference on LHC First Data*, Ann Arbor, USA, December 2010.

Visits to other Institutes:

1. CERN, Geneva, Switzerland, August-November, 2010.
2. Indian Association for Cultivation of Science, February, 2011.

Invited Lectures/Seminars:

1. *Resonant sparticle production at the LHC*, Northeastern University, Boston, MA, USA, December 2010.
2. *Resonant sparticle production at the LHC*, University of Wisconsin-Madison, Madison, WI, USA, December 2010.
3. *Event generators and jet algorithms in the context of LHC*, Visva Bharati, Santiniketan, January 2011.

Academic recognition/Awards:

- MCnet Short-term Studentship, 2010.

Dhiraj Kumar Hazra

Research Summary:

Detail analysis of various single field inflationary models that can produce features in the primordial power spectra and comparison of the models with the recent Cosmic Microwave Background (CMB) angular power spectra.
Study of non-local features in the primordial power spectra and comparison of the features with recent and forthcoming CMB datasets.
Dynamics of two field inflationary models and non-gaussianities of various single field inflationary models.

Publications:

1. D. K. Hazra, M. Aich, R. K. Jain, L. Sriramkumar and T. Souradeep, *Primordial features due to a step in the inflaton potential*, JCAP **1010:008**,2010

Preprints:

1. M. Aich, D. K. Hazra, L. Sriramkumar and T. Souradeep, *Oscillations in the inflaton potential: Exact numerical analysis and comparison with the recent and forthcoming CMB datasets*, *In preparation.*

Conference/Workshops Attended:

1. *CMB rapid response meeting*, Tata Institute of Fundamental Research , Mumbai, India, April 6-8, 2010.

2. *Field theoretic aspects of gravity (FTAG)*, Garhwal University, Uttarakhand, India, April 19-23, 2010.

3. *Summer School in Cosmology*, International Center for Theoretical Physics, Trieste, Italy, July 19-30, 2010.

4. *Primordial Features and Non-Gaussianities (PFNG)*, Harish-Chandra Research Institute, Allahabad, India, December 14-18 , 2010.

5. *Indian Association for General Relativity and Gravitation*, Harish-Chandra Research Institute, Allahabad, India, January , 2011.

Visits to other Institutes:

1. Inter university Center for Astronomy and Astrophysics, Pune, India, July, 2010,

Invited Lectures/Seminars:

1. Presented a talk titled "Primordial features with a step and the tensor contribution" at *CMB rapid response meeting*, Tata Institute of Fundamental Research , Mumbai, India, April 6-8, 2010.

2. Presented a talk titled "Primordial features with a step and the tensor contribution" at *Field theoretic aspects of gravity (FTAG)*, Garhwal University, Uttarakhand, India, April 19-23, 2010.

3. Presented a poster at the poster session titled "Primordial features due to a step in the inflaton potential" at *Summer School in Cosmology*, International Center for Theoretical Physics, Trieste, Italy, July 19-30, 2010.

4. Presented a talk titled "Primordial features due to a step in the inflaton potential" at

   Primordial Features and Non-Gaussianities (PFNG), Harish-Chandra Research Institute, Allahabad, India, December 14-18 , 2010.

5. Presented a talk titled "Oscillations in the inflaton potential: Exact numerical analysis and comparison with the recent and forthcoming CMB datasets" at

   26th meeting of Indian Association for General Relativity and Gravitation, Harish-Chandra Research Institute, Allahabad, India, January 19-21, 2011.

Other Activities:

1. I have been the tutor of "Classical electrodynamics" course for the semester August - December, 2010

Girish Kulkarni

Research Summary:

My research centres on the astrophysics of galaxy formation and the evolution of intergalactic medium (IGM) in early universe. With my collaborators, I worked on three problems in this field in the last academic year.

Firstly, we considered evolution of the IGM in overdense regions of the universe. In the early universe, formation of galaxies is expected to ionize and heat the IGM. We showed that in overdense regions that are usually the subject of observations, this effect is enhanced. We also showed that this enhancement has an effect on the luminosity function of observed galaxies and that this effect can act as an independent probe of evolution of the IGM because of its sensitivity to the IGM properties.

Secondly, we studied formation rate of dark matter haloes in cosmology. This quantity is an important component of the kind of calculations described above and can be calculated from the halo mass function. However, it is difficult to calculate accurately. The commonly used method of calculating halo formation rate fails when applied to the accurate forms of halo mass function. We showed that this is because of failure of a central assumption of the method, namely that the halo destruction rate efficiency is scale indepedent. We then calculated the formation rate using a different, more accurate method and compared the result with measurements from numerical simulations, to find good agreement.

Finally, we consider the formation of galactic nuclei with multiple supermassive black holes. Almost all nearby galaxies with a nuclear stellar bulge are found to contain a supermassive black hole. These black holes are expected to form out of mergers of smaller black holes in early universe. We show, however, that at sufficiently early times, the supply of new black holes to the interiors of a galaxy is rapid enough to result in formation of nuclei with multiple supermassive black holes. Furthermore, we simulate the above process by using highly accurate numerical simulations and calculate the likelihood of occurrence of nuclei of multiple supermassive black holes.

Publications:

1. Girish Kulkarni and Tirthankar Roy Choudhury, *Reionization and feedback in overdense regions at high redshift,* Monthly Notices of the Royal Astronomical Society **412**, 2789, (2011)

Preprints:

1. Sourav Mitra, Girish Kulkarni, J. S. Bagla, Jaswant K. Yadav, *Formation rates of Dark Matter Haloes,* 1103.5828

Conference/Workshops Attended:

1. *Hydrogen Cosmology Workshop*, Harvard University, USA, May 2011

Visits to other Institutes:

1. National Centre for Radio Astrophysics, Pune, June 2010
2. Institute for Theory and Constitution, Harvard University, USA, August 2010–May 2011,
3. Institute d'astrophysique de Paris, Paris, France, November 2010

Invited Lectures/Seminars:

1. *Introduction to Astrophysics*, SERC School on Astronomy and Astrophysics, National Centre for Radio Astrophysics, Pune, June 2010
2. *Reionization and feedback in overdense region at high redshifts*, Institute for Theory and Computation, Harvard University, October 2010
3. *Early reionization and Cosmic Reionization*, Institute d'astrophysique de Paris, Paris, France, November 2010

Other Activities:

1. Visited Harvard University, USA from August 2010 to May 2011 as a Fulbright-Nehru fellow
2. Acted as a guest faculty member at the SERC school on astronomy and astrophysics, held at the National Centre for Radio Astronomy, Pune in June/July 2010.

Shailesh Lal

Research Summary:

In this year I along with Rajesh Gopakumar and Rajesh K. Gupta have looked at the problem of calculating the one-loop partition function in thermal Anti de-Sitter (AdS) spacetimes for particles with arbitrary spin. We addressed this problem through the heat kernel approach, which reduces the problem essentially to harmonic analysis on the given spacetime. This is a great simplification because AdS spacetimes are instances of coset spaces on which the results relevant to us are encoded in a small number of group-theoretic entities, which we were able to exploit even for the case of thermal AdS. In particular, we were able to solve for the one-loop partition function for an arbitrary-spin particle on any odd-dimensional thermal AdS spacetime, and determine the answer in terms of quadratic Casimirs and characters of the Lorentz group, and the special orthogonal group. These results are a generalisation of those obtained previously by analogous methods by David, Gaberdiel and Gopakumar for AdS_3 in arXiv:0911.5085. In particular, they include the cases AdS_5 and AdS_7 which play a central role in the AdS/CFT correspondence and we expect that our results will be of utility in probing the leading quantum effects in those space-times.

Publications:

1. Shailesh Lal and Suvrat Raju, *Rational Terms in Theories with Matter,* JHEP **1008**, 022, (2010)

Preprints:

1. Rajesh Gopakumar, Rajesh K. Gupta, Shailesh Lal, *The Heat Kernel on AdS_{2n+1},* arXiv:1103.3627

Conference/Workshops Attended:

1. *Advanced Strings School*, India, October, 2010.
2. *Indian Strings Meet*, India, January, 2011.
3. *QFT 2011*, India, February, 2011.
4. *Spring School on Superstring Theory and Related Topics*, March 2011.

Visits to other Institutes:

1. Indian Institute of Science, Bengaluru, India, May, 2010,
2. Jawaharlal Nehru University, New Delhi, India, October, 2011.

Invited Lectures/Seminars:

1. *The Heat Kernel on AdS_5 and application*, Indian Strings Meet, Puri, January, 2011.
2. *The Heat Kernel on AdS_{2n+1}*, The International Centre for Theoretical Physics, Trieste, Italy, March 2011.

Sourav Mitra

Research Summary:

Areas of research are Cosmology, structure formation in the Universe, intergalactic medium and reionization - mainly, semi-analytical modelling of cosmological reionization and comparison with observations.

Publications:

1. Mitra, Sourav; Choudhury, T. Roy; Ferrara, Andrea, *Reionization constraints using principal component analysis,* MNRAS **413**, 1569, (2011)

Preprints:

1. Mitra, Sourav; Kulkarni, Girish; Bagla, J. S.; Yadav, Jaswant K., *Formation rates of Dark Matter Haloes,* eprint arXiv:1103.5828

2. Mitra, Sourav; Choudhury, T. Roy; Ferrara, Andrea, *Principal Component Analysis of Reionization History using CMB and QSO Absorption Line Data,* (in preparation)

Conference/Workshops Attended:

1. 29^{th} *Astr. Soc. India (ASI) Scientific meeting*, India, February, 2011.

2. *The Twenty Sixth Meeting of the Indian Association for General Relativity and Gravitation (IAGRG-26)*, India, January 2011.

3. *Primordial Features and Non-Gaussianities (PFNG)*, India, December, 2010.

4. *SERC School on Astronomy and Astrophysics (SERC 2010)*, India, June-July, 2010.

Visits to other Institutes:

1. NCRA, Pune, India, July, 2010.

Invited Lectures/Seminars:

1. *Observational constraints on reionization using principal component analysis*, 29^{th} ASI meeting, Pt. Ravishankar Shukla University, Raipur, India, February, 2011.

2. *Observational constraints on reionization using principal component analysis*, IAGRG-26, HRI, Allahabad, India, January 2011.

3. *Formation rates of Dark Matter Haloes*, SERC 2010, NCRA, Pune, India, July, 2010.

Satyanarayan Mukhopadhyay

Research Summary:

During this academic year I have worked on the very striking same-sign multi-lepton signatures of new physics at the Large Hadron Collider (LHC). This signature is almost free from standard model backgrounds and it occurs with very high cross-sections in supersymmetry with lepton number violation. Furthermore, the Majorana property of the decaying lightest supersymmetric particle (neutralino) can lead to very distinctive patterns in various multi-lepton channels. I have also worked on the problem of discriminating new physics models predicting a low missing-energy signature at the LHC. The essential idea is to capture the information about the underlying mass spectrum and to some extent the spin of the decaying new particles by using various kinematic distributions. In the model building side, I have worked on the problem of Higgs mass bounds in variants of supersymmetric theories in the presence of extra space-like dimensions. The stringent upper bound on the lightest CP-even Higgs mass in minimal supersymmetric theories can be considerably relaxed in such a scenario, if supersymmetry-breaking occurs at a relatively lower scale.

Publications:

1. Kirtiman Ghosh, Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, *Discrimination of low missing energy look-alikes at the LHC*, JHEP **1010**, 096, (2010)

2. Biswarup Mukhopadhyaya, Satyanarayan Mukhopadhyay, *Same-sign trileptons and four-leptons as signatures of new physics at the Large Hadron Collider,* Phys.Rev.D **82**,031501, (2010)

Preprints:

1. Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, Soumitra SenGupta, *Low-scale SUSY breaking by modular fields and Higgs mass bounds,* arXiv:1103.3678 [hep-ph]

2. Biswarup Mukhopadhyaya, Satyanarayan Mukhopadhyay, *Discovering new physics at the LHC by same-sign multi-lepton signatures: a detailed study,* in preparation

Conference/Workshops Attended:

1. *Advanced School on Radiative Corrections for the LHC*, Saha Institute of Nuclear Physics, Kolkata, India, 04 - 11 April, 2011.

2. *18th International Conference on Supersymmetry and Unification of Fundamental Interactions*, Physikalisches Institut, Bonn, Germany, 23rd - 28th August, 2010 .

3. *PreSUSY 10 Workshop*, Bonn, Germany, 19th - 21st August, 2010.

4. *Gearing up for LHC Physics, PSI Summer School on Particle Physics*, Zuoz, Switzerland, August 1 - 7, 2010.

Invited Lectures/Seminars:

1. *Same-sign multileptons at the LHC*, Parallel session talk in the 18th International Conference on Supersymmetry and Unification of Fundamental Interactions, Bonn, Germany, August, 2010.

Other Activities:

1. Teaching assistant for Statistical Mechanics course, January-May, 2011.

Sabyasachi Tarat

Research Summary:

Study of the properties of clean and disordered s-wave superconductors across the $BCS - BEC$ regime, with particular emphasis on the properties of the normal state.

Preprints:

1. S. Tarat and Pinaki Majumdar, *Pairing Fluctuations and Anolamous Transport above the BCS-BEC Crossover in the Two Dimensional Attractive Hubbard Model,* arxiv:1105.1156v1

Rajarshi Tiwari

Research Summary:

In the current year I finished working on double perovskites with single magnetic site in 3-D (e.g. Sr_2FeMoO_6, an FM half metal), where the system faces a serious *geometrically induced magnetic frustration* as the magnetic site of the material lies on an effective FCC lattice. The results are documented in the preprint-1, which was in preparation last year. We also extended this study to models with more than one conduction bands, and wish to include the interaction of the lattice with magnetism, so that the model can describe the physics of a wider variety of double perovskites.

As a small digression, I also studied the AF-Heisenberg model defined on FCC lattice in context of NiO/MnO, as a part of collaborative program of Indo-EU ATHENA project (preprint-2). This also is a direct example of a frustrated antiferromagnet. For the relevant couplings for NiO/MnO, the frustration was less severe. We characterized the ground state, and estimated transition temperature T_c.

We studied Hubbard model (hoppings t, t' and on-site repulsion U) on anisotropic triangular lattice, using Hubbard-Stratonovich transformation in static approximation, where e^--e^- interaction term is linearized by introducing new fields which couple to e^- density and spin, and in static approximation are assumed classical. This maps an interacting many body problem to a coupled field-fermion quadratic problem, which then can be solved with similar methods already developed for older problems. This model is known to be relevant for a class of organics κ-$(ET)_2X$ which show 'pressure' driven Metal insulator transition (MIT). Knowing t'/t being the frustration parameter, we study the ground state in $(\frac{U}{t}, \frac{t'}{t})$ plane, and their thermal evolution. We map out the ground state magnetic phase diagram, MIT boundary, and the thermally driven MIT, near the MIT boundary in the insulating phases. We established the T_cs of the magnetic orders and thermally driven MITs.

Preprints:

1. Rajarshi Tiwari and Pinaki Majumdar, *Non-collinear Magnetic Order in the Double Perovskites: Double Exchange on a Geometrically Frustrated Lattice,* arXiv:1105.0148

2. T. Archer, C.D. Pemmaraju, S. Sanvito, C. Franchini, J. He, A. Fil-

ippetti, P. Delugas, D. Puggioni, V. Fiorentini, R. Tiwari, P. Majumdar, *Exchange interactions and magnetic phases of transition metal oxides: benchmarking advanced ab initio methods,* arXiv:1105.0647

3. Rajarshi Tiwari and Pinaki Majumdar, *Hubbard Model on anisotropic triangular lattice: Frustrated Mott insulators* (in preparation)

Conference/Workshops Attended:

1. *Free and Open Source Softwares (FOSS) workshop*, Pune, India, July 2010

2. *Training on GPU programming with PGI accelerator programming model and PGI CUDA FORTRAN*, Bangalore, India, August, 2010

3. *ICTS Condensed Matter Program 2010*, Mysore, India, December 2010

Visits to other Institutes:

1. Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, India, august 2010,

2. Sardinian Laboratory for Computational Materials Science, University of Cagliari, Cagliari, Italy, January 2011.

Other Activities:

1. Learnt a C++ like graphical programming language 'asymptote' as an interesting academic hobby, using which appealing scientific figures can be drawn. Many of the figures shown in preprints mentioned above are made using it.

2. Volunteered in help to organize *Workshop on Physics of Strong Correlation at H.R.I.*, November, 2010.

3. Volunteer in help to organize *International School on Functional Materials*, March, 2011.

Subrat Kumar Das

Research Summary:

I joined the institute in March 2009 and started a problem on "spin-wave excitations in inhomogeneous magnets", in close collaboration with Prof. Pinaki Majumdar and Mr. Viveka Nand Singh. Till the end of the academic year 2009-10 we could finish the analytical calculations and some numerical results. During the academic year 2010-11 we calculated the main results and tried to analyse those. The analysis part was very difficult and took a longer time. We almost prepared the manuscript with title "Domain Structure and Magnon Spectrum in Disordered Double Perovskite Ferromagnets". Now we are finalizing it and will be submitted to journal within a month.

In the mean time I started another piece of work on "magnetic impurities in s-wave superconductors". As a fresher to this area I devoted some time for basics of superconductivity. Now the analytical calculations are finished and I am setting up the numerical part which will be finished within a couple of weeks. Then we will do our main calculations.

Preprints:

1. Subrat Kumar Das, Viveka Nand Singh, and Pinaki Majumdar, *Domain Structure and Magnon Spectrum in Disordered Double Perovskite Ferromagnets,* (in preparation)

Conference/Workshops Attended:

1. *School on Functional Materials*, India, March 2011.
2. *Workshop on Correlated Electron Systems*, India, November 2010.

Sanjoy Datta

Research Summary:

The achievement of Bose-Einstein condensation has led to vigorous research activities in ultracold systems. Intense research has led to the development of optical lattices, created by interfering two counterpropagating coherent laser beams. These optical lattices are used extensively to probe the physics of strongly correlated electronic systems, such as superfluidity in strongly interacting fermions. Although superfluidity in fermionic systems has been demonstrated in a single trap, the same is eagerly awaited in an optical lattice. This is because, current experimental techniques can not reduce the entropy, S, per particle below $log_e 2 \approx 0.7$, which is almost an order of magnitude higher compared to the theoretically calculated value. This makes it necessary to study the nature of the superfluidity for these systems at temperature attainable in current experiments. In this regard we have studied the well known negative U Hubbard model in the strong coupling limit and in presence of the external trap, which is unavoidable in case of optical lattices. First we have derived an effective Hamiltonian using Hubbard-Stratonovich transformation followed by static approximation. This effective Hamiltonian has been studied using traveling cluster algorithm (TCA). The advantage of our method is that we can study very large system sizes and can access any temperature. This is not possible by other theoretical or numerical techniques. We have calculated the density, double occupancy, pair correlation, quasiparticle density of states and momentum distribution at $T = 0$ and also at temperature which is attainable in experiments. We have shown that in the strong coupling limit, the superfluid state at $T = 0$ leaves an imprint even at temperature of our interest in those above mentioned calculated quantities, which can be measured experimentally.

Apart from this, there is another field of research which is being pursued intensely. This field is known as spintronics. One of the main objective of the field is to have a fully polarized tunable spin current. Previously it has been shown theoretically that such a spin polarized current with limited amount of tunability can be achieved in a quantum wire network. To obtain complete polarization, this theory relies on the interplay of Aharonov-Bohm phase induced by an external magnetic flux and the phase induced by Rashba spin-orbit coupling (RSO). We have been able to show that a fully polarized spin current with complete tunability can be achieved in this quantum wire network by introducing Dresselhaus spin orbit cou-

pling (DSO) along with the RSO coupling and external magnetic flux.

Preprints:

1. Sanjoy Datta, Viveka Nand Singh, Pinaki Majumdar, *Thermally Fluctuating Inhomogeneous Superfluid State of Strongly Interacting Fermions in an Optical Lattice,* arXiv:1104.4912 .

2. Sanjoy Datta, G. V. Pai, T. P. Pareek ,*Completely Tunable Spin Filter* (in preparation).

Conference/Workshops Attended:

1. *ICTS Condensed Matter Programme*, India, December, 2010.

Visits to other Institutes:

1. University of Vienna, Vienna, Austria, January, 2011,

Other Activities:

1. I was the teaching assistant for the Advanced Condensed Matter Course offered by Dr. G. V. Pai during August-November, 2011.

Bobby Ezhuthachan

Research Summary:

I have spent some time studying a class of superconformal theories on $R \times S^2$ and together with Shinji Shimasaki I showed that these theories are related to a class of Super Yang Mills theories via a form of dimensional reduction, but carried out in configuration space. This procedure has been called the 'Novel Higgs Mechanism' in the literature. We also found a class of supersymmetric solutions in these superconformal theories and identified them with configurations in their dual gravitational description. These results will be appearing soon in two papers we are writing up now.

Another work I was involved in during this period, was with Prof. Jatkar and Shinji Shimasaki. The idea was as follows. It can be shown that if we want to have an interacting theory of massless spin-one fields which has any non trivial solution at all, then the theory must have non-abelian gauge invariance. We were able to show that for a special class of scale invariant theories of spin-one fields in three dimensions the requirement of having non trivial solutions, basically implied the existence of a three-algebra. These algebras have previously appeared in the String Theory literature in the context of theories with large amount of super symmetries. Our work shows that they are also necessary for some class of theories (with no reference to super symmetry) to have any nontrivial solution at all. This work is not yet published.

Preprints:

1. BOBBY EZHUTHACHAN, SHINJI SHIMSAKI, SHUICHI YOKOYAMA, *ABJM and Super Yang-Mills theories on* $R \times S^2$ (in preparation)

2. BOBBY EZHUTHACHAN, DILEEP JATKAR, SHINJI SHIMASAKI, *self-consistent interactions of spin-one fields in three dimensions and three algebras* (in preparation)

Conference/Workshops Attended:

1. *Indian Strings Meeting- Puri* India, January, 2011

Visits to other Institutes:

1. Chennai Mathematical Institute, Chennai, India, May, 2010,
2. Institute Of Mathematical Sciences, Chennai, India, June, 2010.
3. Indian Institute Of Science, Bangalore, India, July, 2010
4. Institute Of Mathematical Sciences, Chennai, India, January, 2011.

Kirtiman Ghosh

Research Summary:

During the last academic year (2010-2011), I have studied the collider phenomenology of different new physics scenario in the context of the Large Hadron Collider (LHC). I have investigated the signals of *minimal Universal Extra Dimension (mUED)* model at the LHC operating at $\sqrt{s} = 7$ TeV. In another project, I have studied the possibility of discrimination between different new physics models at the LHC. In particular, we have considered different *low missing energy look-alike scenarios* namely, supersymmetry with R-parity violation, Universal Extra Dimensions with both KK-parity conserved and KK-parity violated and the Littlest Higgs model with T-parity violated. I have also investigated the collider phenomenology of an invisibly decaying Higgs boson in the frame work of a particular variant of *Majoron model*. The brief description of these studies are presented in the following.

In the mUED model, Kaluza-Klein (KK) parity conservation ensures that $n = 1$ KK states can only be pair produced at colliders and the lightest KK particle is stable. Thus, the decay of $n = 1$ KK particles will always involve missing transverse energy ($\not{E}_T$) as well as leptons and jets. I explore the mUED discovery potential of the LHC with $\sqrt{s}$ = 7 TeV in the multileptonic final states. Since in the early LHC run, precise determination of $\not{E}_T$ may not be possible, I examine the LHC reach with and without using $\not{E}_T$ information. I observe that $\not{E}_T$ cut will not improve mUED discovery reach significantly. I have found that opposite sign di-lepton channel is the most promising discovery mode and with first fb^{-1} of collected luminosity, LHC will be able to discover the strongly interacting $n = 1$ KK particles with masses upto 800 $\sim$ 900 GeV.

The problem of discriminating possible scenarios of TeV scale new physics with large missing energy signature at the Large Hadron Collider (LHC) has received some attention in the recent past. We consider the complementary, and yet unexplored, case of theories predicting much softer missing energy spectra. We have outlined a systematic method based on a combination of different kinematic features which can be used to distinguish among different possibilities. These features often trace back to the underlying mass spectrum and the spins of the new particles present in these models. As examples of "low missing energy look-alikes", we consider Supersymmetry with R-parity violation, Universal Extra Dimensions with both KK-parity conserved and KK-parity violated and the Littlest

Higgs model with T-parity violated by the Wess-Zumino-Witten anomaly term. Through detailed Monte Carlo analysis of the four and higher lepton final states predicted by these models, we show that the models in their minimal forms may be distinguished at the LHC, while non-minimal variations can always leave scope for further confusion. We find that, for strongly interacting new particle mass-scale ~ 600 GeV (1 TeV), the simplest versions of the different theories can be discriminated at the LHC running at $\sqrt{s} = 14$ TeV within an integrated luminosity of 5 (30) fb^{-1}.

In another study, we consider the collider phenomenology of a singlet Majoron model with softly broken lepton number. Lepton number is spontaneously broken when the real part of a new singlet scalar develops vacuum expectation value. With the additional soft terms violating lepton numbers, the imaginary part of this singlet scalar becomes a massive pseudo-Majoron which can account for the dark matter. In presence of the coupling of the pseudo-Majoron with the Standard Model (SM) Higgs, the SM Higgs mostly decays into a pair of pseudo-Majorons, giving rise to missing transverse energy signals at a hadron collider. Since the Higgs visible decay branching fractions get reduced in presence of this invisible decay mode, the bounds on the SM Higgs mass from the LEP and Tevatron experiments get diluted and the invisible decay channel of the Higgs become important for the discovery of low mass Higgs at the Large Hadron Collider.

Publications:

1. D. Choudhury, A. Datta and K. Ghosh, *Deciphering Universal Extra Dimension from the top quark signals at the CERN LHC,* JHEP **1008**, 051 (2010)

2. B. Bhattacherjee and K. Ghosh, *Search for the minimal universal extra dimension model at the LHC with $\sqrt{s}$=7 TeV,* Phys. Rev. D **83**, 034003 (2011)

3. Kirtiman Ghosh, Satyanarayan Mukhopadhyay and Biswarup Mukhopadhyaya, *Discrimination of low missing energy look-alikes at the LHC,* JHEP **1010**, 096 (2010)

Preprints:

1. Kirtiman Ghosh, Biswarup Mukhopadhyaya and Utpal Sarkar, *Signals of an invisibly decaying Higgs in a scalar dark matter scenario: a study for the Large Hadron Collider,* arXiv:1105.5837 [hep-ph]

Conference/Workshops Attended:

1. *Dark Matter in LHC Era: Direct & Indirect Searches*, India, January, 2011.

2. *Discussion Meeting on LHC*, India, January, 2011.

3. *Advanced School on Radiative Corrections for the LHC*, India, April, 2011.

Sushan Konar

Research Summary:

The observed accreting millisecond X-ray pulsars (AMXPs) typically belong to ultracompact binaries undergoing mass transfer at very low rates from low-mass companions. Though the average $P^{\rm spin}$ of the AMXPs is smaller than that of MSRPs, the average $B^{\rm surface}$ tends to be higher (a trait similar to globular cluster MSRPs (Konar 2010)). However, a long period of accretion should result in a smaller magnetic field (Konar & Bhattacharya 1997). The AMXPs are also close to the theoretical spin-up line, requiring a phase of near-Eddington accretion. Thus the positions of AMXPs in the $B - P$ plane is counter-intuitive. We investigate the magnetic field evolution of neutron stars in ultra-compact binaries and see that many of the features of AMXPs can be explained by accretion-induced screening of the magnetic field.
Collaborator - Dipankar 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.

A neutron star has two physically different regions - a metallic outer crust ($\sim$ 1 km thick and $\rho \sim 10^6 - 10^{14.5}$ gm.cm^{-3}) and a fluid inner core (radius $\sim$ 10 km and $\rho_{\rm average} \sim$ few $\times\ 10^{15}$ gm.cm^{-3}). The core consists chiefly of super-fluid neutrons and super-conducting protons. The rotation of the star is supported by the Onsager-Feynman vortices in the neutron super-fluid and the magnetic field threads the proton superconductor as Abrikosov fluxoids. There is observational indication for the decay of the magnetic field. But the actual decay of the field can only occur through the ohmic dissipation of the currents in the crust where the electrical conductivity is finite. A phase of flux-expulsion to the crust is then required prior to dissipation. As a result of spin-down the vortices in the neutron super-fluid move out of the core reducing the number of vortices there. Inter-pinning between the rotational vortices and the magnetic fluxoids make the fluxoids move outwards too, resulting in the expulsion of a frac-

tion of the magnetic flux. We investigate the nature of this expelled flux and how it may transform in the metallic crust and modify the evolution of the surface magnetic field.

Publications:

1. Sushan Konar, *The Magnetic Feilds of Millisecond pulsars in Globular Clusters,* Mon. Not. R. Astron. Soc. **409**, 259, (2010)

Preprints:

1. Sushan Konar, *The Binary Millisecond Pulsars in Globular Clustersj,* (in preparation)
2. Sushan Konar, Dipankar Bhattacharya, *The Accreting Millisecond Pulsars,* (in preparation)
3. Sushan Konar, Dipankar Bhattacharya, *The Magnetic Fields of Neutron Stars, Invited Review to appear in 'Living Reviews in Relativity'* (in preparation)

Visits to other Institutes:

1. ICTP, Trieste, Italy, May-July 2011
2. SISSA, Trieste, Italy, June, 2011

Lectures/Seminars:

1. *Millisecond Pulsars : A tale of two populations*, Astrophysics Seminar, HRI, Allahabad, September 2010
2. *Millisecond Pulsars in Globuar Clusters*, Astrophysics Seminar, SISSA, Trieste, June 2011

Other Activities:

1. Acted as a tutor for the course *General Theory of Relativity* given by Prof. Narayan Banerjee in the *Summer School in Gravitation & Cosmology* conducted at HRI, May 2010.

2. Served as a referee for Monthly Notices of Royal Astronomical Society, Research in Astronomy & Astrophysics and Pramana.

Supervised the following students for their summer projects -

1. Apratim Ganguly, St. Xavier's College Calcutta - Strange Stars
2. Monika Soraisam, IIT Delhi - Binary Millisecond Pulsars
3. Debisree Ray, Calcutta University - Millisecond Pulsars

Shailesh Kulkarni

Research Summary:

We have studied the response of a rotating Unruh-DeWitt detector that is coupled to a massless scalar field which is described by a non-linear dispersion relation in flat spacetime. Unlike, say, the case of the uniformly accelerating detector [Rinaldi (2009),Campo(2010)], defining the transition probability rate of the rotating detector does not lead to any difficulties and, we find that, it can be defined in exactly the manner as in the standard case. Since it seems to be impossible to evaluate the modified Wightman function in a closed form, we had adopted a new method to evaluate the response of the rotating detector. However, as the transition probability rate for the rotating detector proves to be difficult to evaluate analytically, we had to calculate the response of the detector numerically. We have shown that the response of the rotating detector can be computed *exactly* (albeit, numerically) even when it is coupled to a field that is governed by a non-linear dispersion relation. We have illustrated that the Planck scale modifications due to the non-linear dispersion relation turn out to be extremely negligible when the dispersion relation is super-luminal. However, we find that there can be a reasonable extent of changes to the standard results when one considers a sub-luminal dispersion relation. In addition, we have also considered the response of the rotating detector when the field is subjected to a boundary condition on a cylindrical surface located inside the static limit in the rotating frame. It is known that, in the standard case, the rotating detector fails to respond in such a situation [Davies(1996)]. We have shown that the null result remains true even for the case with a modified dispersion relation, provided the dispersion relation is a super-luminal one.
This work is in collaboration with Dr. L.SriramKumar and Dr. Sashideep Gutti.

Publications:

1. S. Gutti, S. Kulkarni and L. Sriramkumar, *Modified dispersion relations and the response of the rotating Unruh-DeWitt detector,* Phys. Rev. D 83, 064011, (2011)

Conference/Workshops Attended:

1. *Primordial Features and non-Gaussianities* HRI, Allahabad, India, Dec-

ember, 2010.

2. *The 26th IAGRG Meeting, Sangam: Confluence of Gravitation and Cosmology* HRI, Allahabad, India, January, 2011.

Visits to other Institutes:

1. Inter University Center for Astronomy and Astrophysics(IUCAA), Pune, India, October-November 2010.

2. Center for Quantum Spacetime (CQUeST), Sogang University, Seoul, South Korea , November-December 2010.

3. Tata Institute of Fundamental Research (TIFR), Mumbai, India, March 2011

Talks/Invited Lectures/Seminars:

1. *Hawking Radiation and Anomalies*, Center for Quantum Spacetime, Seoul, South Korea, December, 2010.

2. *Quantum field theoretic effects with modified dispersion relation*, Center for Quantum Spacetime, Seoul, South Korea, December, 2010.

3. *Perturbations in anisotropic inflationary models induced by a generic scalar field*, IAGRG, Harish Chandra Research Institute, Allahabad, India, January, 2011.

Kumar Meduri Chakravartula

Research Summary:

My research work focuses on the collider signals of extra dimension models, like large and warped extra dimension models, at the LHC. These models predict the existence of a tower of Kaluza-Klein modes that can give rise to missing energy signals or deviations from the SM predictions. For the reliable predictions of these signals at the LHC, where QCD plays an important role, one needs to compute the observable to higher orders in the perturbation theory. In the context of large extra dimension models we have computed the next-to-leading order QCD corrections to the process of graviton plus vector boson ($Z/W^{\pm}$) production at the LHC. We have presented our results in various kinematic distributions for the proton-proton center of mass energy of 14 TeV.

In the context of warped extra dimension model, the KK modes are very heavy and hence will be seen as resonances in the processes like dilepton or diphoton productions. Once a resonance is observed, its spin needs to be identified in order to determine the nature of the resonance and hence possibly to unravel the underlying new physics. In this context, we are working on the spin determination of the graviton resonances using center-edge asymmetry of the photon angular distributions in the diphoton signals. We are in the process of extending the work to look for the role of the QCD corrections in this analysis. The work is in progress.

Publications:

1. M.C. Kumar, Prakash Mathews, V. Ravindran, Satyajit Seth, *Vector boson production in association with KK modes of the ADD model to NLO in QCD at LHC,* Journal of Physics G. **38**, 055001, (2011)

2. M.C. Kumar, Prakash Mathews, V. Ravindran, Satyajit Seth, *Graviton plus vector boson production to NLO in QCD at the LHC,* Nucl. Phys. B. **847**, 54, (2011)

Conference/Workshops Attended:

1. *XIX DAE BRNS Symposium on High Energy Physics*, Jaipur, India, December 2010.

2. *Dark Matter in the LHC Era: Direct and Indirect Searches*, Kolkata,India, January 2011.

3. *Workshop on Synergy between High Energy and High Luminosity Frontiers (SEL11)* , India, January 2011.

4. *Discussion Meeting on LHC*, Santiniketan, January, 2011.

5. *Advanced School on Radiative Corrections for the LHC*, Kolkata, April, 2011.

Invited Lectures/Seminars:

1. *Spin identification of the RS graviton using diphoton signals*, XIX DAE BRNS Symposium on High Energy Physics, LNMIIT, Jaipur, December 2010.

Akhilesh Nautiyal

Research Summary:

Inflation is the most successful paradigm in explaining the large scale homogeneity and isotropy of the universe and also, at the same time, providing seeds for the anisotropy of the cosmic microwave background (CMB) radiation and large scale structure. It predicts adiabatic, nearly scale invariant and nearly Gaussian primordial perturbations that are in excellent agreement with the observations of CMB anisotropies being done by WMAP. During inflation the potential energy of a scalar field, called inflaton, dominates the total energy density of the universe and for this to occur, the potential of the inflaton field has to be sufficiently flat. Till now, there is no compelling particle physics model of inflation that can satisfy this requirement of flat potential as there are large quantum corrections. One way to protect the flatness of the potential is by considering inflaton as pseudo Nambu-Goldstone Boson of some spontaneously broken symmetry. This model is called as natural inflation. The flatness of the potential is protected by the shift symmetry. But to satisfy the observational constraints on the spectral index, the symmetry breaking scale has to be at Planck scale. It was shown by Mohanty et al (Mohanty and Nautiyal 2008) that this scale can be reduced to the GUT scale if one couples this PNGB to radiation as in warm inflation models. Warm inflation is an alternative to the standard picture of inflation. In this model radiation is also present sub-dominantly during inflation and inflaton is coupled to the radiation, which provides the damping effects required for slow-roll. The density perturbations are generated by thermal fluctuations and no reheating is required as the temperature of the universe remains constant during inflation.

However, in these models there is the requirement of generating large dissipative couplings of the inflaton with radiation while at the same time, not de-stabilizing the flatness of the inflaton potential due to radiative corrections. One way to achieve this without fine tuning unrelated couplings is by supersymmetry. We have shown that if the inflaton and other light fields are Pseudo-Nambu-Goldstone Bosons then the radiative corrections to the potential is suppressed and the thermal corrections are small as long as the temperature is below the symmetry breaking scale. In such models it is possible to fulfill the contrary requirements of an inflaton potential which is stable under radiative corrections and the generation of a large dissipative coupling of the inflaton field with other light fields (Mishra, Mohanty and Nautiyal 2011).

There are some models, named as K-inflation, where one can achieve inflation by non standard kinetic terms. We (N. C. Devi, A. Nautiyal and A. a. Sen) consider these models with a DBI type action and do a detail numerical analysis using the potentials of the form $\frac{1}{n}\lambda\phi^n$ and PNGB potential, that are already have been well studied for the canonical case. We consider two cases $n = 2,\ 4$. We have an extra parameter η compared to the canonical case that appears in the non-standard kinetic term. We extend MODCODE (a code to calculate power spectrum for given potential) for the non-canonical case and after performing MCMC analysis we find that for $n = 4$ case we get a small value for the tensor to scalar ratio that is allowed by the recent data and there is a significant improvement in the likelihood function. For the PNGB potential we get a lower value for spontaneous symmetry breaking scale (GUT scale) compared to its value for the canonical case (Planck scale) .

There are a number of evidences, for eg. galactic rotation curves, weak gravitational lensing of distant galaxies by foreground structure, that most of the matter in the galaxies is non-baryonnic (dark matter). Dark matter can be accommodated in the supersymmetric extension of the standard model of particle physics (the LSP (lightest supersymmetric particles)). In was shown by S. Mohanty, S. Rao and D. P. Roy that in wino LSP scenario one can get the correct relic density as well as the hard positron signal reported by the PAMELA experiment with the wino mass of 4.5 TeV. This is achieved because the annihilation cross-section of the winos, gravitationally bound to the galaxies, is boosted by Sommerfield enhancement. Wino LSP annihilates into W^+, W^- and Z that produces photons, electrons and positrons. These particles interact with (intergalactic medium) IGM and can affect the processes of recombination and hence the CMB anisotropy and polarization. We are trying to look for these effects on CMB anisotropy and trying to constraint the mass and annihilation cross-section of heavy wino dark matter.

Preprints:

1. Hiranmaya Mishra, Subhendra Mohanty and Akhilesh Nautiyal, *Warm natural inflation,* arXiv:1106.3039

2. N. Chandrachani Devi, Akhilesh Nautiyal, Anjan A Sen, *Observational Constrains on K-Inflation,* (in preparation)

Conference/Workshops Attended:

1. *Primordial Features and Non-Gaussianities (PFNG-2010)*, HRI India, December 2010,
2. *ICAPP meeting on Dark Matter*, PRL, India, April 2011.

Visits to other Institutes:

1. Physical Research Laboratory, Ahmedabad, India, July-Auguest 2010,
2. Physical Research Laboratory, Ahmedabad, India, Feb-April 2011,

Invited Lectures/Seminars:

1. *Signatures of late time annihilation of Dark Matter in the CMB anisotropy: Heavy wino DM model*, ICAPP Dark matter meeting, Physical Research Laboratory, Ahmedababad, India, April 2011.

Andreas Nyffeler

Research Summary:

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).

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.

Publications:

1. A. Nyffeler, *Hadronic light-by-light scattering contribution to the muon $g-2$,* Chin. Phys. **C34**, 705, (2011)

2. D.K. Ghosh, A. Nyffeler, V. Ravindran *et al., Working group report: Physics at the Large Hadron Collider,* Pramana **76**, 707, (2011)

Preprints:

1. D. Babusci *et al.*, *On the possibility to measure the $\pi^0 \to \gamma\gamma$ decay width and the $\gamma^*\gamma \to \pi^0$ transition form factor with the KLOE-2 experiment* (in preparation)

Conference/Workshops Attended:

1. *Discussion Meeting on Physics at the LHC*, Santiniketan, India, Jan 2011
2. *The Hadronic Light-by-Light Contribution to the Muon Anomaly*, Seattle, USA, February – March 2011
   Talk: Hadronic light-by-light scattering in the muon $g-2$: Chiral approach and resonance dominance

Visits to other Institutes:

1. Laboratori Nazionali Frascati (LNF), Italy, May – June 2010 (3 weeks)
2. University of Rome 2 - Tor Vergata, Italy, June 2010 (1 day)
3. University of Milan, Milan, Italy, June 2010 (2 days)
4. INFN Padova, Italy, June 2010 (2 days)
5. Department of Physics, University of Bern, Switzerland, November 2010 (1 week)

Invited Lectures/Seminars:

1. *Theory of the muon $g-2$: some recent developments*, University of Rome 2 - Tor Vergata, Italy, June 2010
2. *Theory of the muon $g-2$: some recent developments*, University of Milan, Italy, June 2010
3. *Theory of the muon $g-2$: some recent developments*, INFN Padova, Italy, June 2010
4. *Das anomale magnetische Moment des Myons: warum es auf die 9. Stelle nach dem Komma ankommt*, Heinrich Greinacher Award Colloquium, University of Bern, Switzerland, November 2010
5. *Theoretical status of the muon $g-2$*, University of Bern, Switzerland, November 2010

Academic recognition/Awards:

- Greinacher Prize 2010, awarded by the Department of Physics, University of Bern, Switzerland: *for my fundamental contribution to the theory of the anomalous magnetic moment of the muon and for my exemplary devotion to research in theoretical physics*.

Other Activities:

1. Together with V. Ravindran (HRI), Rahul Basu (IMSc, Chennai), D. Indumathi (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, funded by the International Centre for Theoretical Sciences (ICTS), TIFR, Mumbai. Preparing lectures on the basics of perturbative QCD for the Advanced School. Continuing work since August 2009.

2. Responsibility of associateship and visitor programme of the Regional Centre for Accelerator-based Particle Physics (RECAPP) at HRI and help in organization of academic meetings of RECAPP (with A. Datta, B. Mukhopadhyaya and V. Ravindran), since May 2010.

3. Coordinator of Working Group "Physics at the LHC" at the XIth Workshop on High Energy Physics Phenomenology (WHEPP XI), held at Ahmedabad, India, in January 2010 and preparation of Working Group report for proceedings (with D.K. Ghosh and V. Ravindran), during 2010.

4. Pheno lunch talk: Charge asymmetry in $W+$ jets production at the LHC (based on arXiv:1004.3404 [hep-ph]), May 2010.

5. Guiding one beginning Ph.D. student (M.K. Mandal) of V. Ravindran on a project: "Higgs physics: from LEP to LHC", since Dec 2010.

6. Physics Colloquium, HRI: The anomalous magnetic moment of the muon: why the 9th decimal place matters, January 2011.

7. Series of introductory lectures on "The Muon $g-2$" at HRI, Jan-May 2011.

Suvrat Raju

Research Summary:

In the academic year 2010 – 2011, I explored the application of techniques developed to study scattering amplitudes in flat space to the AdS/CFT conjecture. The past few years have seen an intense study of scattering amplitudes in gauge and gravity theories. These studies have been undertaken both for computational reasons — including the computation of amplitudes at the Large Hadron Collider — but also for formal reasons — to enhance our understanding of Quantum Field Theory. A central role, in this activity, has been played by what are called the BCFW recursion relations which relate higher point amplitudes to products of lower point amplitudes. The BCFW recursion relations had previously only been applied to quantum field theories in flat space.

In work first reported in November 2010, and then extended throughout the year, I was able to generalize the BCFW recursion relations to quantum field theories in a particular kind of curved space, called anti-de Sitter space. By the AdS/CFT correspondence, amplitudes in anti-de Sitter space are dual to correlation functions in a conformal field theory that lives on the boundary of this space. Thus, this gives a new technique to compute correlation functions in such conformal field theories. This is again of interest both for computational and formal reasons. From a computational viewpoint, even the four point function of the stress tensor has not been computed using AdS/CFT, and hopefully this new technique will provide a method of doing that. From a formal viewpoint, this will hopefully shed some light on the analytic properties of the Operator Product Expansion that plays a central role in conformal field theory.

With Matthias Gaberdiel (ETH, Zurich) , Rajesh Gopakumar (HRI) , and Thomas Hartman (IAS, Princeton), I also commenced work on investigating a new conjectured duality between higher spin theories in AdS and a solvable conformal field theory on its boundary. I also continued to work with Shailesh Lal (HRI) on investigating simplifications in the amplitudes of quantum field theories with matter.

Publications:

1. Shailesh Lal and Suvrat Raju, *Rational Terms in Theories with Matter,* JHEP **08**, 022, (2010)

2. Suvrat Raju, *Generalized Recursion Relations for Correlators in the Gauge-Gravity Correspondence,* Phys. Rev. Lett. **106**, 091601, (2011)

3. Suvrat Raju and M. V. Ramana, *The Other Side of Nuclear Liability,* Economic and Political Weekly, **45**, 48, (2010).

Preprints:

1. Suvrat Raju, *BCFW for Witten Diagrams,* arXiv:1011.0780

2. Suvrat Raju, *Recursion Relations for AdS/CFT Correlators,* arXiv:1102.4724

3. Matthias R. Gaberdiel, Rajesh Gopakumar, Thomas Hartman, Suvrat Raju, *Partition Functions of Holographic Minimal Models,* arXiv:1106.1897

Conference/Workshops Attended:

1. *Indian Strings Meeting*, India, January, 2011.

2. *Summer Symposium*, Germany, July-August 2010.

3. *ICTS Workshop on Applied String Theory*, India, March, 2011.

Visits to other Institutes:

1. Institute for Advanced Study, Princeton, USA, March–April 2010.

2. Perimeter Institute for Theoretical Physics, Waterloo, Canada, April 2010.

3. Brown University, USA, April 2010.

4. Harvard University, USA, April 2010.

5. DESY, Hamburg, Germany, July-August 2010.

6. University of Amsterdam, Netherlands, August 2010

7. Jawaharlal Nehru University, Delhi, October 2010.

8. Indian Institute of Technology, Indore, January 2011.

9. Indian Institute of Science, Bangalore, March 2011.

10. Tata Institute of Fundamental Research, March 2011.

Invited Lectures/Seminars:

1. *Next to Simplest Quantum Field Theories*, Institute Seminar, Perimeter Institute for Theoretical Physics, Canada, April 2010.
2. *Next to Simplest Quantum Field Theories*, Departmental Seminar, Brown University, USA, April 2010.
3. *Next to Simplest Quantum Field Theories*, Duality Seminar, Harvard University, USA, April 2010.
4. *Next to Simplest Quantum Field Theories*, University Seminar, University of Amsterdam, Netherlands, August 2010.
5. *BCFW for Witten Diagrams*, Indian Strings Meeting, Puri, January 2011.
6. *Black Holes and the Gauge Gravity Duality*, Institute Seminar, Indian Institute of Technology, Indore, January 2011.
7. *Recursion Relations for AdS/CFT Correlators*, Departmental Seminar, Indian Institute of Science, Bangalore, March 2011.
8. *BCFW for Witten Diagrams*, Workshop on Applied String Theory, Tata Institute for Fundamental Research, Mumbai, March 2011.

Academic recognition/Awards:

- Ramanujan Fellowship, 2010.

Other Activities:

1. Refereed papers for the following journals
   (a) Nuclear Physics B (Elsevier)
   (b) Physical Review D (American Physical Society)
   (c) General Relativity and Gravitation (Springer)
   (d) Central European Journal of Physics (Springer)
2. Wrote a number of articles, including opinion pieces and book reviews for various newspapers and magazines throughout the year.

R. Prabhu

Research Summary:

I am interested in the broad research area of **Quantum Information Theory**. 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 including achieving secure quantum cryptography, faster quantum computers, and better quantum communication. Quantum entanglement in many-body systems has created considerable interest recently because of its potential in understanding quantum many body phenomena, which are not amenable to classical perceptions, such as quantum phase transitions, decoherence, etc. Also, quantum entanglement forms a central element in bringing together many-body physics and quantum information science, and hence in the development of new exciting physics. Properties of entanglement in many-body systems like cold atomic gases in optical lattices, trapped gaseous Bose-Einstein condensates, and spin models have been dealt with increasing interest in recent times.
During the academic year 2010-2011, at HRI along with my collaborators Dr. Aditi Sen De and Dr. Ujjwal Sen, I am involved in studies of entanglement properties in quantum spin chains. We have shown that quantum correlations can have statistical mechanical properties like ergodicity, which is not inherited from the corresponding classical correlations and magnetizations, for the transverse anisotropic quantum XY model in one-, two-, and quasi two-dimension, for suitably chosen transverse fields and temperatures. This work has been submitted for publication in an international journal. Currently, I am involved in studies of behavior of the dense coding capacity and generalized geometric measure in ordered and disordered XY-spin system. During this academic year, I have attended two workshops and had an academic visit to Bangalore University, Bengaluru. I was part of local organizing committee in organizing the event *International School and Conference on Quantum Information Processing and Applications* which was held from 14th to 20th February 2011 at HRI.

Preprints:

1. R. Prabhu, Aditi Sen(De), and Ujjwal Sen, *Ergodicity from Nonergodicity in Quantum Correlations of Low-dimensional Spin Systems,* arXiv:1103.3836, (2011)

Conference/Workshops Attended:

1. *Workshop on Quantum Chaos and Quantum Information*, India, July, 2010

2. *Workshop on quantum information science*, India, November-December, 2010.

3. *International School and Conference on Quantum Information Processing and Applications*, India, February, 2011.

Visits to other Institutes:

1. Department of Physics, Bangalore University, Bengaluru, India, December 2010.

Other Activities:

1. Took part in organizing the *International School and Conference on Quantum Information Processing and Applications* which was held from 14th to 20th February 2011 at HRI.

Mina Ketan Parida

Research Summary:

In this work the prospects of creating baryon asymmetry of the universe via low-scale leptogenesis, while evading the well known gravitino problem in supersymmetric $SO(10)$ grand unified theory, is successfully explored using a novel mechanism. We use Higgs representations $\mathbf{126_H} \oplus \overline{\mathbf{126}}_\mathbf{H}$, $\mathbf{16_H} \oplus \overline{\mathbf{16}}_\mathbf{H}$, and three extra singlet neutrinos $(\mathbf{T_i}, \mathbf{i} = \mathbf{1}, \mathbf{2}, \mathbf{3})$. A light singlet neutrino of mass $\sim 10^5$ GeV is shown to have small mixings with heavy ($\sim 10^9 - 10^{11}$ GeV) right handed neutrinos and decays to generate flavor dependent lepton asymmetry which is converted to baryon asymmetry by sphaleron effects. A further interesting aspect of the model is that the doublet vacuum expectation value in $\overline{16}_H$ triggers the desired mixings while it induces large triplet vaccum expectation value that breaks intermediate left-right symmetry with large right-handed neutrino masses. The Type-I seesaw contribution cancels out while Type-II seesaw contribution is negligible for neutrino mass, the dominant contribution being through inverse seesaw. The model works with hierarchial as well as inverted hierarchial light neutrino masses. Testable predictions of the model are leptophillic right-handed doubly charged Higgs bosons accessible to high energy accelerators and proton lifetime for $p \to e^+\pi^0$ within one order longer than the current experimental limit.

In a separate investigation we show how gauge coupling unification is successfully implemented through non- supersymmetric grand unified theory (GUT), $SO(10) \times G_f(\ G_f = S_4\ , SO(3)_f,\ SU(3)_f)$, using low-scale flavor symmetric model of the type $SU(2)_L \times U(1)_Y \times SU(3)_C \times S_4$ recently proposed by Hagedorn, Lindner, and Mohapatra, while assigning matter-parity discrete symmetry for the dark matter stability. For gauge coupling unification in the single-step breaking case, we show that a color-octet fermion and a hyperchargeless weak-triplet fermionic dark matter are the missing particles needed to complete its MSSM-equivalent degrees of freedom. When these are included the model automatically predicts the non-supersymmetric grand unification with a scale identical to the MSSM-GUT scale. We also find a two-step breaking model with Pati-Salam intermediate symmetry where the DM and a low-mass color-octet scalar or the fermion are signaled by grand unification. The proton-lifetime predictions are found to be accessible to ongoing or planned searches in a number of models. We discuss grand unified origin of the light fermionic triplet DM, the color-octet fermion, and their phenomenology.

Publications:

1. Mina K. Parida and Amitava Raychaudhuri, *Inverse see-saw, leptogenesis, observable proton decay and $\Delta_{\rm R}^{\pm\pm}$ in SUSY $SO(10)$ with heavy W_R,* Phys. Rev. **D 82**, 093017, (2010).

2. Mina K. Parida, Pradip K. Sahu and Kalpana Bora, *Flavor unification, dark matter, proton decay, and other observable predictions with low-scale S_4 symmetry,* Phys. Rev. **D 83**, 093004, (2011).

Conference/Workshops Attended:

1. *Neutrinos in Physics, Astrophysics and Cosmology*, India, February, 2011.

2. *Interface of Cosmology and Particle Physics (iCaPP) Meeting on Dark Matter*, India, April, 2011.

Visits to other Institutes:

1. Physical Research Laboratory, Ahmedabad, India, April, 2011.

2. Institute of Physics, Bhubaneswar, India, May, 2011.

Invited Lectures/Seminars:

1. *Dark matter and proton stability through $SO(10)$ and flavour symmetry* , iCaPP Meeting on Dark Matter, Physical Research Laboratory, Ahmedabad, April, 2011.

2. *Predictive unification, dark matter, and neutrino masses*, Theoretical Physics Seminar Circuit, Institute of Physics, Bhubaneswar, May, 2011.

Academic Recognition/Awards:

- Pranakrushna Parija Sammana in Physics, 2011.(Award conferred by late Pranakrushna Parija Memorial Foundation, Cuttack, Orissa)

Joint Colloquia

1. Bruce Mellado Garcia: Results from the LHC
2. Patrick Peter: Bouncing cosmology, a new way to solve old puzzles
3. Sumathi Rao: Graphene: Nobel Prize 2010.
4. Jayaram Chengalur: Galaxy Evolution: The Dwarf Perspective.
5. Pratima Sinha: Transmission of Genetic Information during cell division.
6. W. Miller Goss: Under the Radar- The first woman in Radio Astronomy, Ruby Payne- Scott.

Mathematics Talks and Seminars

1. D.N. Verma: Representation Theory AND the NP concept in Computer Science.
2. Pierre Matsumi: Galois representation of Abelian variety over p-adically punctured discs.
3. N.S.N. Sastry: An introduction to Coxeter groups.
4. Pinaki Sarkar: Introduction to Wireless Sensor Networks: A Mathematical view point.
5. Herve Queffelec: Compostion operators: a bridge between Lagrange And Hardy- Littlewood.
6. Archana S. Morye: On the Serre- Swan Theorem, and on vector bundles over real abelian varieties.
7. G. Kasi Viswanadham: Phragmen- Lindel of theorem.
8. Akilesh P. Duerling Selberg functions.
9. Jay Mehta: Introduction to Elliptic curve cryptosystems.
10. P. Mishra: A cusp catastrophe in minimal surface.

11. P. Rai: Homological Techniques in Group theory.
12. Saikat Chatterjee: Parallel transport on path space and double category.
13. Amitabha Lahiri: Non- abelian strings and surface holonomy.
14. V. BalaJi: Vector Bundles: Abelian and non abelian aspects of Mathematics.
15. V.Balaji: Parahoric bundles and parabolic bundles.
16. Claire Levaillant: Reducibility of the Lawrence Krammer representation of the braid group.
17. Ron Kerman: Sobolev Imbeddings on general domains via Isoperimetric Inequalities.
18. Ron Kerman: Series of introductory lectures on Orlicz Spaces.
19. Andrzej Schinzel: Prime Factors of Values of Polynomials.
20. Gautam Pai: Sequences of Positive Integers Containing No. K terms in Arithmetical progression.

Physics Talks and Seminars

1. Young Minh: The circumnuclear Disk(CND) of our Galactic Center.
2. Dhiraj Kumar Hazra: Primordial features and non- Gaussianities.
3. Shailesh Lal: The Heat Kernel for Higher- Spin Fields of AdS_{2n+1}.
4. Abhiram Soori: Conductance of Tomonaga- Luttinger Liquid wires and junctio.ns with resistances .
5. Saurav Mitra: Reionization constraints using principal component analysis .
6. João Gomes: Exact holography for small black holes.
7. Mahendra Kumar Verma: Dynamo Transition and Reversals.
8. Sanjit Mitra: Planck Mission: Goals, Early results and Analysis Challenges.
9. Jyotirmoy Bhattacharya: Dissipative superfluid dynamics from gravity.
10. S. Sridhar: MHD TURBULLENCE.
11. Mu-Chun Chen: Leptogenesis.
12. Boris Kayser: Lecture on Neutrino Physics.
13. Prabodh Shukla: Nonequilibrium phenomena in random- field models .
14. R. Shankar: Nonequilibrium phenomena in random- field models.
15. Suman Majumdar: Matched Filter Detection of Ionized Bubbles During Epoch of Reionization.
16. Debashish Chowdhury: Kinetics of molecular motors: understanding principles of nature's nano technology.
17. R. Prabhu: Statistical behavior of entanglement and other quantities in finite spin chains in an external transverse filed.
18. Andreas Nyffeler: The anomalous magnetic moment of the muon: why the 9^{th} decimal place matters.

19. Jozef Gruska: Physics and Informatics as two windows to explore the world.

20. Anindya Biswas: BEC: A Quantum Many- Body Approach.

21. Sanjay Gupta: Physics of interface: Mott insulator barrier sandwiched between two metallic planes.

22. Nabyendu Das: Quantum critically in ferroelectrics.

23. Priya Natrajan: Feast and famine: The life of black holes in the univers.e

24. Sourav Bhattacharya: Black holes and the positive cosmological constant.

25. Soumini Chaudhury: A model for dark matter halo in milky way: Implications for direct detection of WIMPs

26. Hung- Yi Pu: Accretion Disks in Black Hole X-ray Binaries and Jet formation.

27. Patrick Peter: Currents in cosmic strings and associated cosmology

28. Shinji Shimasaki: Some aspects of BPS solutions in ABJM theory and their gravity duals.

29. Rejish Nath: Rydberg Excitations: From Bose-Einstein Condensates to Spin Models.

30. J.P. Singh: Axial Vector and Pseudo Scalar current.

31. Justin David: Hydrodynamics of R-Charged D1 -branes.

32. Anshuman Maharana: Models of Particle Physics from Branes and Singularities.

33. Naresh Dadhich: Gravity in higher dimensions.

34. Mira Dey: Strange Quark Matter and Strange Stars.

35. Jishnu Dey: Strange Star, Pion Gas and hydrodynamics, nuclear-particle physics and astrophysics.

36. Sarika Jalan: Universal and non- universal properties of complex networks: a random matrix approach.

37. Sarika Jalan: Synchronization on Complex Networks.

38. D G Kanhere: Thermodynamics of Clusters: Higher than bulk melting points, Disordered broadened specific heats and size sensitive melting.

39. Sayantani Bhattacharyya: Wilsonian Approach to Fluid / Gravity Duality.

40. Gautam Bhattacharya: Fermionic vacuum and the signature of the Schwinger term.

41. Sushan Konar: Millisecond Pulsars: A tale of two populations.

42. Jayendra Bandyopadhyay: Quantum chaotic system as a model of decohering environment.

43. Jayendra Bandyopadhyay: A new signature of Quantum Chaos.

44. M.C. Kumar: QCD corrections to the graviton production in extra dimensional theories at the LHC. item Gaurav Goswami: The origin of features in primordial powder spectra.

45. Sujoy Kumar Modak: Black Hole Thermodynamics: Semi- Classical Approaches and Beyond.

46. Sashideep Gutti: Modified dispersion relation and the response of a rotating Unruh-deWitt detector.

47. Amit Ghosal: Strong Correlation Driven " Wigner"- Physics in Circular Quantum Dots.

48. Aranya Bhattacherjee: Cavity quantum optomechanics of ultracold atoms in an optical lattice.

49. Rajaram Nityananda: Light scattering in soft matter, happy hunting ground for quantum mechanics.

50. Anirban Basu: Recursive Structures in String theory.

51. T.V.Ramakrishnan: Ginzburg- Landau Theory for High Temperature Superconductivity in cuprates.

52. A. P. Balachandran: Pauli- Forbidden Transitions From Noncommutative Spacetimes.

53. Prasenjit Ghosh: Atomistic Modeling of materials.

54. Atul Chhotrray: Classical and semi- classical aspects of black holes.

55. Pravabati Chingangbam: Search for primordial non- Gaussian signals in the CMB.

56. Ramlal Awasthi: Adjoint $SU(5)$ and grand Unification.

57. Atri Bhattacharya: Diffuse UHE neutrino flux and non-standard physics.

58. Girish Kulkarni: Reionization in biased regions.

59. Emmanuel Rollinde: Nucleosynthesis constraints on cosmology.

60. Shailesh Lal: Matter contributions to Gluon Amplitudes.

61. Sanjeev Kumar: Spin- Orbital frustrations in undoped iron-pnictides.

62. Yoshinori Matsuo: Another Realization of Kerr/CFT Correspondence.

63. Deepak Vaid: Elementary Particles as Universal Quantum Computational Gates.

64. Ayan Mukhopadhyay: Non- Equilibrium Aspects of Gauge/Gravity Duality.

65. Rajesh Gupta: Corrections to the extremal black hole entropy.

Recent Graduates

1. **Anamitra Mukherjee**, *Field Induced Melting of Charge Order in Manganites*, Homi Bhabha National Institute; June 21, 2010.

2. **Tanusree Pal**, *Integrable Representations of Lie Tori and An Invariant of Real Forms of Twisted Affine Kac-Moody Lie Algebras*, Homi Bhabha National Institute; June 25, 2010.

3. **Nishikanta Khandai**, *Non-linear Gravitational Clustering in the Universe*, Homi Bhabha National Insitute; July 15, 2010.

4. **Subhaditya Bhattacharya**, *Supersymmetry with non-universal High-scale parameters and the large Hadron collider*, Homi Bhabha National Institute; July 26, 2010.

5. **Rajesh Kumar Gupta**, *Classical and Quantum Connections to Entropy of Extremal Black Hole*, Homi Bhabha National Institute; September 20, 2010.

6. **Ayan Mukhopadhyay**, *Non-Equilibrium Aspects of Gauge/Gravity Duality*, Homi Bhabha National Institute; September 3, 2010.

7. **Shamik Banerjee**, *Counting Microscopic Degeneracy of N=4 Black Hole*, Homi Bhabha National Institute; September 15, 2010.

8. **Soumya Das**, *Some Problems on Jacobi Forms*, Homi Bhabha National Institute; November 18, 2010.

9. **Arjun Bagachi**, *Non-Relativistic Limit of the AdS/CFT Conjecture*, Homi Bhabha National Institute; January 14, 2011.

Publications

Sukumar Das Adhikari

1. Sukumar Das Adhikari, A. A. Ambily and B. Sury, *Zero-sum problems with subgroup weights,* Proc. Indian Acad. Sci. (Math. Sci.) 120, No. 3, 259–266 (2010).

2. Sukumar Das Adhikari and Mohan N. Chintamani, *Number of weighted subsequence sums with weights in* $\{1, -1\}$ Integers, to appear.

Punita Batra

1. Punita Batra,Volodymyr Mazorchuk, *Blocks and Modules for Whittaker pairs,* Journal of Pure and Applied Algebra, **215**(2011),1552-1568.

Kalyan Chakraborty

1. Kalyan chakraborty, *On the Chowla-Selberg integral formula for non-holomorphic Eisenstein series* Integral Transformations and Special Functions, Vol.21, No.12, 2010, 917–923

2. K. Chakraborty, S. Kanemitsu and X. -H. Wang, *The modular relation and the digamma function* Kyushu J. Math. 65, 2011, 39–53.

Chandan Singh Dalawat

1. Chandan Singh Dalawat, *Further remarks on local discriminants*, Journal of the Ramanujan Mathematical Society **25** 4, 391–417 (2010). Cf. arXiv:0909.2541.

2. Chandan Singh Dalawat, *Primary units in cyclotomic fields*, to appear in the Annales des sciences mathématiques du Québec. Cf. arXiv:0911.2566.

3. Chandan Singh Dalawat, *Final remarks on local discriminants*, Journal of the Ramanujan Mathematical Society **25** 4, 419–432 (2010). Cf. arXiv:0912.2829.

4. Chandan Singh Dalawat, *Serre's "formule de masse" in prime degree*, published online 30/12/2010 on Springerlink, to appear in Monatshefte für Mathematik. Cf. arXiv:1005.2016.

5. Chandan Singh Dalawat, *Splitting primes*, to apper in Math Unlimited: Essays in Mathematics, Science Publishers, Delhi. Cf. arXiv:1007.4426.

Rukmini Dey

1. Rukmini Dey, Samir Paul, *Quillen bundle and Geometric Quantization of non-abelian vortices,* Proc.Indian Acad. Sci (Math. Sci.) **Vol 121, No. 1**, pg. 1-9, (2011)

Ramakrishnan B.

1. S. Gun, M. Manickam and B. Ramakrishnan, *A canonical subspace of modular forms of half-integral weight*, Math. Ann. **347**(2010), 899–916.

2. Jaban Meher and B. Ramakrishnan, *A note on Pseudo-Eigenvalues of the Atkin-Lehner W-Operators*, Proceedings of 20th Annual Conf. of Jammu Math. Soc. 2010, pp. 1–7 (2011).

Ratnakumar Peetta Kandy

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

R. Thangadurai

1. R. Balasubramanian and R. Thangadurai, *Collected works of S. Sivasankaranarayana Pillai*, Collected works series, Ramanujan Mathematical Society, **1**, (2010).

2. M. Ram Murty and R. Thangadurai, *The class number of* $\mathbf{Q}((-p)^{1/2})$ *and digits of* $1/p$*,* Proc. Amer. Math. Soc., **139**, 1277-1289, (2011)

Manoj Kumar

1. I. B. S. Passi, Mahender Singh and Manoj K. Yadav, *Automorphisms of abelian group extensions,* J. Algebra **324**, 820-830, (2010).

Gyan Prakash

1. Jean-Marc Deshouillers and Gyan Prakash, *Large zero-free subsets of* $\mathbf{Z}/p\mathbf{Z}$, Integers **11**, 399-420, (2011)

Sanjaykumar Hansraj Amrutiya

1. Sanjay Amrutiya and Indranil Biswas, *On the F–fundamental group scheme,* Bull. Sci. Math. **134**, 461-474, (2010)

Mohan Namdev Chintamani

1. M. N. Chintamani, B. K. Moriya and P. Paul, *The number of weighted n-sums,* Int. J. Mod. Math. 5, no. **2**, 215-222, (2010).

Jaban Meher

1. W. Kohnen and J. Meher , *Some remarks on the q-exponents of generalized modular functions,* The Ramanujan Journal, **15, no.1**, 115-119, (2011).

2. J. Meher and B. Ramakrishnan, *A note on Pseudo-Eigenvalues of the Atkin-Lehner W-Operators,* Proceedings of 20th Annual Conf. of Jammu Math. Soc. 2010, 1-7, (2011).

Bhavin K. Moriya

1. M. N. Chintamani, B. K. Moriya and P. Paul, *The number of weighted n-sums,* Int. J. Mod. Math. 5, no. **2**, 215-222, (2010).

Rajesh K. Srivastava

1. R. K. Srivastava and R. Rawat, *Spherical means in annular regions in the n-dimensional real hyperbolic spaces,* Proc. Indian Acad. Sci. Math. Sci. (**accepted**), DOI: arXiv:0908.2289v1

Sandhya Choubey

1. S. Choubey, S. F. King and M. Mitra, *On the Vanishing of the CP Asymmetry in Leptogenesis due to Form Dominance,* Phys. Rev. D **82**, 033002, (2010)

2. A. Bhattacharya, S. Choubey, R. Gandhi and A. Watanabe, *Ultra-high neutrino fluxes as a probe for non-standard physics,* JCAP **1009**, 009, (2010)

3. A. Bhattacharya, S. Choubey, R. Gandhi and A. Watanabe, *Diffuse Ultra-High Energy Neutrino Fluxes and Physics Beyond the Standard Model,* Phys. Lett. B **690**, 42, (2010)

4. S. Chakraborty, S. Choubey, S. Goswami and K. Kar, *Collective Flavor Oscillations Of Supernova Neutrinos and r-Process Nucleosynthesis,* JCAP **1006**, 007, (2010)

5. S. Choubey and M. Mitra, *Spontaneous R-Parity Violating Type III Seesaw,* JHEP **1005**, 021, (2010)

6. S. Choubey, T. Schwetz and C. Walter, *Working Group 1 Report (Theory),* AIP Conf. Proc. **1222**, 65 (2010)

Tirthankar Roy Choudhury

1. Susumu Inoue, Ruben Salvaterra, Tirthankar Roy Choudhury, Andrea Ferrara, Benedetta Ciardi, Raffaella Schneider, *Probing intergalactic radiation fields during cosmic reionization through gamma-ray absorption,* Monthly Notices of the Royal Astronomical Society **404**, 1938, (2010)

2. Tapomoy Guha Sarkar, Somnath Bharadwaj, Tirthankar Roy Choudhury, Kanan Datta, *Cross-correlation of the HI 21-cm signal and Lyα forest: a probe of cosmology,* Monthly Notices of the Royal Astronomical Society **410**, 1130, (2011)

Tapas Kumar Das

1. Czerny, B., Lachowicz, P., Dovčiak, M., Karas, V., Pecháček, T., & Das, T. K., *The model constraints from the observed trends for the quasi-periodic oscillation in RE J1034+396,* Astronomy and Astrophysics **524**, id.A26, (2010)

2. Das, T. K., *Behaviour of Relativistic Matter Close to the Black Hole Event Horizon,* Proc. Astronomical Society of the Republic of China 2010 Scientific Assembly ASROC2010, (2010)

3. Das, T. K., & Czerny, B., *Modeling the time-resolved quasi-periodic oscillations in active galactic nuclei,* Monthly Notices of the Royal Astronomical Society **Online Early Version**, DOI: 10.1111/j.1365-2966.2011.18427.x, (2011)

4. Das, T. K., & Czerny, B., *Hysteresis effects and diagnostics of the shock formation in low angular momentum axisymmetric accretion in the Kerr metric,* New Astronomy **In Press**, (2011)

5. Nag, S., Acharya, S., Ray, A. K., & Das, T. K., *The role of flow geometry in influencing the stability criteria for low angular momentum axisymmetric black hole accretion,* New Astronomy **In Press**, (2011)

AseshKrishna Datta

1. AseshKrishna Datta, Kyoungchul Kong, Konstantin T. Matchev, *Minimal Universal Extra Dimensions in CalcHEP/CompHEP,* New J.Phys. **12**, 075017, (2010), published in July, 2010.

Aditi Sen De

1. Aditi Sen(De) and Ujjwal Sen, *Quantum Advantage in Communication Networks*, Physics News **40**, 17 (2010).

2. Sibylle Braungardt, Mirta Rodríguez, Aditi Sen(De), Ujjwal Sen, Roy J. Glauber, and Maciej Lewenstein, *Counting of fermions and spins in strongly correlated systems in and out of thermal equilibrium*, Phys. Rev. A **83**, 013601 (2011).

Rajesh Gopakumar

1. A. Bagchi, R. Gopakumar, I. Mandal and A. Miwa, *GCA in 2d*, JHEP **1008**, 004, (2010).

2. M. R. Gaberdiel, R. Gopakumar and A. Saha, *Quantum $\mathcal{W}$-Symmetry in AdS_3*, JHEP **1102**, 004, (2011).

3. M. R. Gaberdiel and R. Gopakumar, *An AdS_3 Dual for Minimal Model CFTs*, Phys. Rev. **D83**, 066007, (2011).

Dileep P. Jatkar

1. Ling-Yan Hung, Dileep P. Jatkar, Aninda Sinha, *Non-relativistic metrics from back-reacting fermions,* Classical and Quantum Gravity **28**, 015013, (2011)

2. Dileep P. Jatkar, Aninda Sinha, *New Massive Gravity and AdS_4 counterterms,* Physical Review Letters **106**, 171601, (2011)

Pinaki Majumdar

1. Viveka Nand Singh and Pinaki Majumdar, *Antisite Domains in Double Perovskite Ferromagnets: Impact on Magnetotransport and Half-metallicity,* Europhys. Lett. **94**, 47004, (2011)

Biswarup Mukhopadhyaya

1. Kirtiman Ghosh, Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, *Discrimination of low missing energy look-alikes at the LHC*, JHEP **1010**, 096, (2010)

2. Satyanarayan Mukhopadhyay, Biswarup Mukhopadhyaya, *Same-sign trileptons and four-leptons as signatures of new physics at the CERN Large Hadron Collider*, Phys. Rev **D82**, 031501, (2010)

3. Pradipta Ghosh, (IACS, Kolkata) , Paramita Dey, Biswarup Mukhopadhyaya, Sourov Roy, *Radiative contribution to neutrino masses and mixing in $\mu\nu$SSM*, JHEP **1005**, 087, (2010)

4. Nishita Desai, Biswarup Mukhopadhyaya, *R-parity violating resonant stop production at the Large Hadron Collider*, JHEP **1010**, 060, (2010)

5. Biswarup Mukhopadhyaya, Pran Nath *et al.*, *The Hunt for New Physics at the Large Hadron Collider*, Nucl. Phys. Proc. Suppl **200-202**, 185, (2010)

6. 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)

7. 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)

Satchidananda Naik

1. Author: Satchidananda Naik, *Closed String Field Theory for Super Twistors and Maximal Supergravity ,* Progress of Theoretical Physics Supplement No 188 page 126 (2011)

Sudhakar Panda

1. S. Panda, M. Sami and I. Thongkool, *Reheating the D-brane Universe via preheating,* Phys. Rev. **D 81**, 103506, (2010)
2. S. Panda, M. Sami and J. Ward, *Bounds on Tensor wave and Twisted Inflation,* Phys. Rev. **D 82**, 103511, (2010)

Arun Kumar Pati

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Sumathi Rao

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About the Computer Section

1. Local Area Network with Optical Fiber Cable Giga backbone and with Gigabit node connectivity was set up in the Institute and Library building.
2. A new Network Storage Systems (NAS) with more centralised data storage with redundancy and automated backup facility has been installed.
3. Newer versions of different flavors of Linux operating systems were loaded on the desktops.
4. A new gateway machine for secure remote login was set up for the users.
5. Webmail server for the Institute was upgraded for the Institute e-mail users.
6. New internal mail server and domain name server were set up.
7. Computing related to conferences were held in the conference computer room.
8. New versions of several applications software were loaded on users' systems, computer centre and conference room systems.
9. All the computer centre NIS client machines were upgraded with Ubuntu (LTS).
10. Four 80 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.
11. Expansion of wireless networking to cover up most of the places of Institute building and library building has been done.
12. A few Laptops for faculty members were purchased.

Current activities and plans:

1. Tender has been published for the purchase of new Linux/Windows based high end desktops for faculty members, post doctoral fellows, research scholars and administrative members of the institute.

2. Tender has been published for the purchase of new iMac desktops for the faculty members of the institute.

3. Tender has been published for the upgradation of institute's Mail Server, Name Server, Web Server, and firewall servers.

4. Purchase of a few high end mono laser printers and a colour printer is being processed.

5. Upgradation of a few laptops used by students and faulty members is under plan.

Library

The Institute's library is one of the best-equipped libraries in the region. Being a research institute, it provides the required support to the academic and research activities. It remained open on all working days between 8 a.m. to 2 a.m. including Saturdays. It also remained open during the Sundays and the Gazzetted holidays from 10 a.m. to 6 p.m. It had added 821 (Eight hundred twenty one) new books, thus making the total number of books to 19868 (Nineteen thousand eight hundred sixty eight) which includes 780 books as gifted ones. It has also added 2544 bound volumes of the journals during the period from 1st April 2010 to 31st March 2011, it has increased bound volumes collection to 34718. The institute's library has a total collection of 54586 (Fifty four thousand five hundred eighty six) of books and bound volumes. The library had 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 it reflected no loss of titles in books or journals.

During the last year basic emphasis had been provided to create more space for users. The library had shifted some of the less used back volumes to the first floor storage area and created some more reading space for the users by rearranging the book and back volume display racks. The library provided better systems to our users for browsing the library OPAC and related search. The library procured one more photocopying machine to provide better photocopying services. The library enriched its 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 online. The Institute Library is providing on-line access of the periodicals to our users for 110(One hundred ten) online titles.

The Library has provided the Web Enabled library catalogue to its users. The library can be termed as 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). The Institute encourages the use of its library by providing library consultation facilities to the research scholars from the neighboring institutes. The Institute had strengthened its library security system made with the implementation of Electro-magnetic Tattle Tapes to reduce the losses. It has been made completely functional.

Construction Activity

1. Tender for Construction of buildings 'Hostel', 'Extension of Institute Building, Library, Computer Centre', 'Engineering building' and 'Community Centre Annexe' at HRI has been finalized. The work has been awarded to M/s Kharaujha Builders Pvt. Ltd., Varanasi. Their work is in progress.

2. Two nos. additional 500 KVA Diesel Generator Sets complete with Diesel Engine, Suitable Alternator, Control panel, Starting and control batteries etc. have been supplied, Installed and Commissioned for giving a back-up power supply in case of power failure from UPPCL.

3. Following miscellaneous works were also carried out during the financial year :

   (a) Supply and installation of FRP cooling towers including Civil and Electrical works for the Institute and Library buildings.

   (b) Providing earthing for Lightning arrestors of various buildings in campus.

   (c) SITC of Electrical cable and Accessories for computing equipments.

   (d) Construction of in house facilities for NKN (National Knowledge Network) project.

   (e) SITC of intelligent fire alarm system for Library building

   (f) Making an infrastructure for String theory project including Civil, Electrical and Air conditioning works etc.

   (g) Supply and installation of new Fire extinguisher in campus.

   (h) Providing and fixing shutter to cover shelves in the kitchen of all housing