हरीश चन्द्र अनुसंधान संस्थान
छतनाग मार्ग, झूँसी, इलाहाबाद - 211 019
Harish Chandra Research Institute
Chhatnag Road, Jhunsi Allahabad – 211 019

Major achievements for the Month - July 2016

In Physics & Mathematics

STRING THEORY

The research of the string theory group has focused on several directions.

- Unitarity of covariant superstring field theory has been proven to all orders in perturbation theory (arXiv: 1607.08244), and a systematic procedure has been given for computing one loop mass renormalization of an arbitrary state in string theory (arXiv: 1607.06500).
- Reality of superstring field theory has been proven (arXiv: 1606.03455), and Cutkosky rules have been derived (arXiv: 1604.01783).
- BV master actions for heterotic and type II string theories have been constructed (JHEP 1602 (2016) 087).
- Zero angular momentum conjecture for supersymmetric black holes has been tested (JHEP 1604 (2016) 082).
- Covariant action for type IIB supergravity has been constructed (JHEP 1607 (2016) 017).
- The effect of cosmologically relevant moduli fields on the spectral tilt of the CMB has been studied (arxiv: 1604.08512).
- The precision CMB observables n_s and r are sensitive to moduli masses, which have been analyzed for some representative models of inflation (Phys.Lett. B751 (2015) 195-200).
- Exact WKB methods have been used to determine Nekrasov partition function of N=2 SUSY SU (2) gauge theory with arbitrary matter in fundamental representation (JHEP 1607 (2016) 115).
- A free field representation of the BMS algebra in 3 dimensions has been given (JHEP 1606 (2016) 024).
- Relations between certain modular graph functions at genus one in type II string theory have been obtained (arxiv: 1606.07084), while the Poisson equations for the three loop ladder diagram (arxiv: 1606.02203) and the Mercedes diagram have been calculated (Class.Quant.Grav. 33 (2016) no.5, 055005).
- Non–analytic terms from nested divergences in maximal supergravity have been obtained (Class.Quant.Grav. 33 (2016) no.14, 145007).
- Certain non-BPS interactions in the type II theory at genus one have been analyzed (Class.Quant.Grav. 33 (2016) no.12, 125028).
- Differential equations satisfied by some BPS couplings in the type II theory have been obtained (Class.Quant.Grav. 33 (2016) no.4, 045002).
- It has been shown that in Lovelock theories Schrodinger geometries occur only when certain relations are satisfied by Lovelock couplings (Nucl.Phys. B910 (2016) 273-292).

CONDENSED MATTER PHYSICS

Magnetism in superconductors

Magnetism and superconductivity are the dominant ordering phenomena in quantum matter but often seem mutually exclusive. There are however situations where the two coexist and the interplay makes for fascinating changes in both the superconductivity and magnetic order.

In two papers published in Physical Review, Madhuparna Karmakar and Pinaki Majumdar uncover aspects of this physics using a recently developed method.

In the paper Phys. Rev. A 93, 053609 (2016) they solve the problem of pairing in a population imbalanced Fermi gas where an applied magnetic field increases the population of one spin species with respect to the other. The resulting magnetised system does allow `traditional' pairing at low imbalance, and then transits to a spatially modulated `FFLO' state. While this result is well known, the physics at finite temperature had remained unexplored. The paper settles this conclusively. Fig.1 shows the experiment-theory comparison.

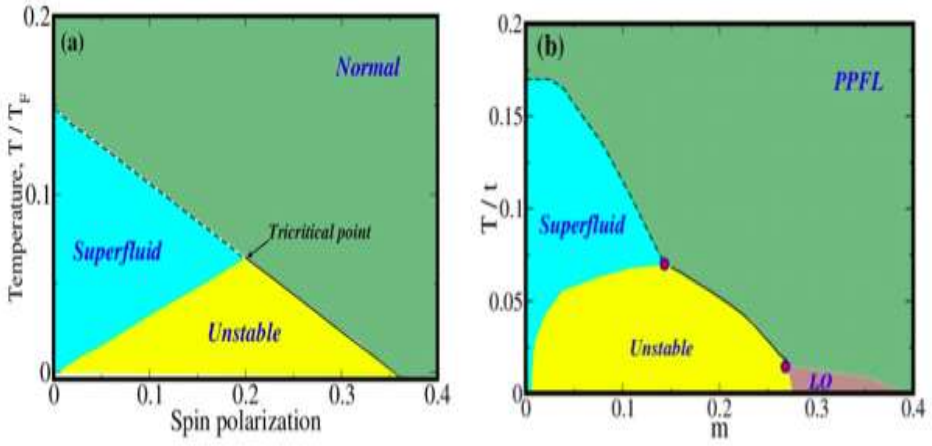
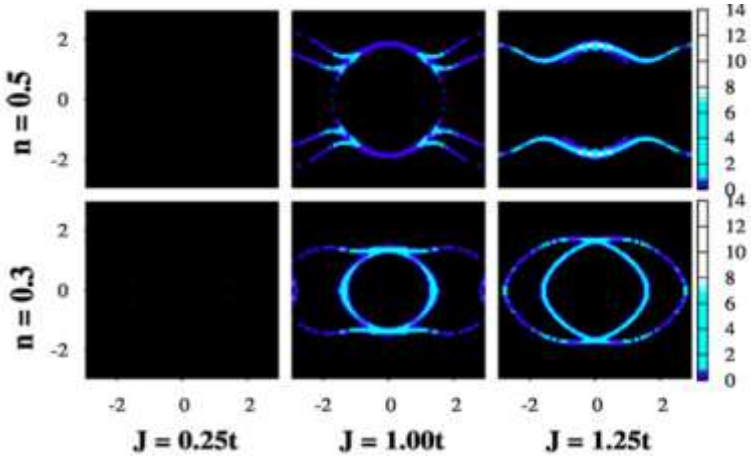


Fig. 1

In the other paper, Phys Rev B 93, 195147 (2016), Karmakar and Majumdar explore spontaneous magnetic and superconducting order in a model that is supposed to mimic the borocarbides. While disordered magnetic moments are expected to suppress superconductivity, the moments in this system manage to order - and their order strongly influences the superconducting state. The cooperative behaviour that emerges survives only at low temperature but hints at a complex superconducting state arising out of a simple interaction. Fig.2 shows the strange Fermi surface in such superconductors, without magnetism there would be no Fermi surface at all, only a dark background.

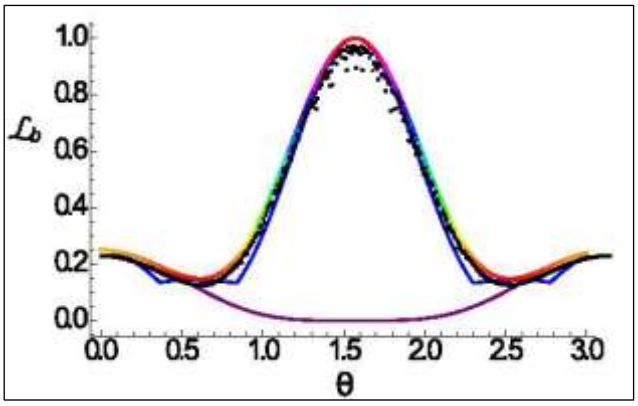


Disclaimer: HRI is publishing its first online monthly report. The work published in this section represents research activities in the recent past.

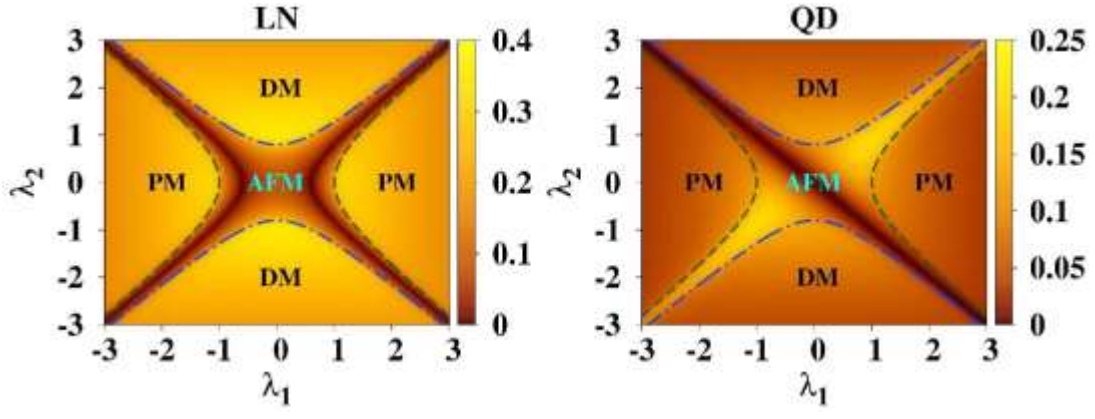
2. Prasenjit Sen presented a talk on their recent research on the novel two-dimensional material phosphorene at the International Conference on Electronic Materials organized by the International Union of Materials Research Societies in Singapore in July 2016.

QUANTUM INFORMATION AND COMPUTATION (QIC)

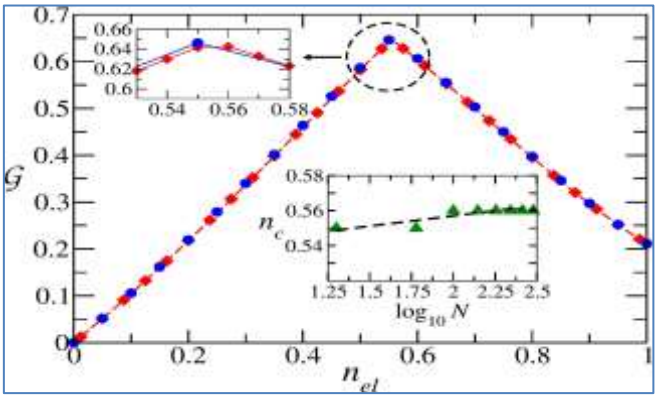
The quantum information and computation (QIC) group at HRI has been working on fundamental aspects of quantum mechanics as well as on quantum devices. In particular, they found stricter bounds on the archetypal quantum property that there exist physical observables that cannot have sharp values in any single state of a quantum system. These uncertainty relations are shown to be tighter than the textbook Roberson-Schröedinger uncertainty relation as well as the others existing in the current literature. See Fig. 1, where a plot of some of the obtained bounds are compared with earlier ones for a certain set of quantum states, and in particular the blue line is for one of the new bounds, while the purple one corresponds to the Roberson-Schröedinger relation.



The group have also been working on the use of paradigmatic quantum many-body systems as quantum devices, and have in particular investigated about features of nonclassical correlations in the alternating field quantum XY model and spontaneous magnetization in disordered quantum XY models. They have also found an analytical method for finding multisite physical properties of large quantum superposition states with defects, and have used it to find a relation of multisite quantum entanglement with high-temperature superconductivity. See Fig. 2, which presents a zero-temperature phase diagram of the alternating field quantum XY model using two measures of quantum correlations. Fig. 3 presents a plot of a genuine multisite entanglement as a function of the amount of defects in a quantum spin-1/2 ladder which helps to relate multisite entanglement with high-temperature superconductivity.



Disclaimer: HRI is publishing its first online monthly report. The work published in this section represents research activities in the recent past.



REFERENCES:

1. arXiv:1607.06712 [pdf, other]
   Tighter Uncertainty and Reverse Uncertainty Relations
   Debasis Mondal, Shrobona Bagchi, Arun Kumar Pati
2. arXiv:1607.05522 [pdf, other]
   Uncertainty Relations for Quantum Coherence
   Uttam Singh, Arun Kumar Pati, Manabendra Nath Bera
   Journal-ref: Mathematics 4, 47 (2016)
3. arXiv:1607.05195 [pdf, other]
   Response to defects in multi- and bipartite entanglement of isotropic quantum spin networks
   Sudipto Singha Roy, Himadri Shekhar Dhar, Debraj Rakshit, Aditi Sen De, Ujjwal Sen
4. arXiv:1606.06985 [pdf, ps, other]
   Necessarily transient quantum refrigerator
   Sreetama Das, Avijit Misra, Amit Kumar Pal, Aditi Sen De, Ujjwal Sen
5. arXiv:1606.01099 [pdf, ps, other]
   Spontaneous magnetization of quantum *XY* spin model in joint presence of quenched and annealed disorder
   Anindita Bera, Debraj Rakshit, Aditi Sen De, Ujjwal Sen
6. arXiv:1605.07576 [pdf, other]
   Static and dynamical quantum correlations in phases of an alternating field XY model
   Titas Chanda, Tamoghna Das, Debasis Sadhukhan, Amit Kumar Pal, Aditi Sen De, Ujjwal Sen
7. arXiv:1604.06683 [pdf, other]
   Genuine multipartite entanglement in superconducting phases of doped quantum spin ladders
   Sudipto Singha Roy, Himadri Shekhar Dhar, Debraj Rakshit, Aditi Sen De, Ujjwal Sen
8. arXiv:1603.05776 [pdf, other]
   Products of weak values: uncertainty relations, complementarity and incompatibility
   Michael J. W. Hall, Arun Kumar Pati, Junde Wu
   Journal-ref: Phys. Rev. A 93, 052118 (2016)
9. arXiv:1603.02801 [pdf, ps, other]
   Conclusive Identification of Quantum Channels via Monogamy of Quantum Correlations
   Asutosh Kumar, Sudipto Singha Roy, Amit Kumar Pal, R. Prabhu, Aditi Sen De, Ujjwal Sen
10. arXiv:1602.08437 [pdf, ps, other]
    Energy Cost of Creating Quantum Coherence
    Avijit Misra, Uttam Singh, Samyadeb Bhattacharya, Arun Kumar Pati
    Journal-ref: Phys. Rev. A 93, 052335 (2016)
11. arXiv:1602.04140 [pdf, ps, other]
    Measuring Electromagnetic Vector Potential via Weak Value
    Arun Kumar Pati
12. arXiv:1601.04742 [pdf, ps, other]
    Effect of non-Markovianity on the dynamics of coherence, concurrence and Fisher information
    Samyadeb Bhattacharya, Subhashish Banerjee, Arun Kumar Pati

HIGH ENERGY PARTICLE PHYSICS

1. Some rather striking sources of diphotons at the Large Hadron Collider have been pointed out. These are especially interesting because they can be linked with extensions of the symmetry group used in the Glashow-Salam-Weinberg electroweak theory, which was thought of with entirely different motivations.

   It has also been shown how the existence of extra spacelike dimensions can lead to diphoton events, not just at the now somewhat debatable 750 GeV peak, but anywhere in the TeV range, for the same type of spacetime geometry that explains the hierarchy between the Planck and electroweak scales.

   References:
   Kasinath Das, Santosh Kumar Rai, Phys.Rev. D93 (2016) 095007
   Nabarun Chakrabarty, Biswarup Mukhopadhyaya, Soumitra SenGupta
   e-Print: arXiv:1604.00885 [hep-ph]

2. Significant theoretical work has taken place at the HRI group on the Deep Underground Neutrino Experiment, with special reference to the signatures of sterile neutrinos. The investigations suggested by the HRI group, in their overall ramifications, can

   i) establish that neutrino oscillation violates CP,
   ii) determine the three-neutrino mass ordering, and
   iii) determine the sources of CP-violating phases that play a crucial role in the neutrino sector.

   References:
   Mattias Blennow, Sandhya Choubey, Tommy Ohlsson, Dipyaman Pramanik (Harish-Chandra Res. Inst.), Sushant K. Raut
   e-Print: arXiv:1606.08851 [hep-ph]

3. Capabilities of long-baseline experiments in the presence of a sterile neutrino
   Debajyoti Dutta, Raj Gandhi, Boris Kayser, Mehedi Masud, Suprabh Prakash
   e-Print: arXiv:1607.02152 [hep-ph]

   New lights have also been thrown on supersymmetry, on theories comprising boson-fermion symmetry in nature, especially in such forms which offer consistency with the observed mass of the Higgs boson.

   References:
   Sbottoms of Natural NMSSM at the LHC
   Jyotiranjan Beuria, Arindam Chatterjee, AseshKrishna Datta
   e-Print: arXiv:1603.08463 [hep-ph]

Achievements in Mathematics

Algebra

A well-known conjecture by Berkovich states that every finite p-group admits a non-inner automorphism of order p. It has been proved that a finite p −group of coclass 3 admits a non-inner automorphism of order p provided $p \neq 3$.

Analysis & Geometry

One of the main results in in Harmonic Analysis, is a characterization of nonlinearities that operates on the modulation space $M^{p,1}(R^n)$. It has also been shown that any nonlinearity that acts on $M^{p,1}(R^n), p \geq 1$ by composition, has to be real analytic. This answers an open question raised by Boaxiang et. al. regarding the action of non linearities of the form $F(u) = |u|^{\alpha}u$ on $M^{p,1}(R^n)$ when α is not an even integer, in connection with the well posedness of the nonlinear Schrödinger equation with power type nonlinearity.

In Geometry, it has been shown that any asymptotically harmonic manifold in dimension 3 is a symmetric space. This completes the classification of asymptotically harmonic manifolds in dimension 3.

Number Theory

Given such a set of natural numbers A and an integer $K \geq 1$, one may ask, generalising a problem posed by A. Sárközy, for the smallest natural number $a(K)$ such that when A is partitioned into K disjoint subsets, every large enough integer is expressible as a sum of no more than $a(K)$ elements of A, all belonging to some one subset of the given partition of A. It has been shown that $a(K) \leq K\, exp\left(\frac{3\, log\, 2+o(1)\log K}{\log\log K}\right)$ when A is the set of squares.

D. Zagier in the year 1981 conjectured that the series $\sum_{n=1}^{\infty}\tau^2(n)\exp(-nz)$ behaves asymptotically when $z \to 0$, in terms of the zeors of the Riemann zeta function $\zeta(s)$. Hafner and Stopple recently have verified this conjecture assuming Riemann hypothesis. It has been proved that the Lambert series $\sum_{n=1}^{\infty}c^2(n)\exp(-nz)$ also behaves asymptotically in terms of the zeros $\zeta(s)$ when $z \to 0$, where $c(n)$ is the nth Fourier coefficient of any cusp form f over $T = SL(2, Z)$.

A conjecture of Bravo et. al. (2013) says that the Diophantine equation

$$2x^2 + 1 = 3^b y^m$$

has no solution in positive integers x, $b, y\ and\ m$, where the integers b and m are even, $y > 1$ and $m > 2$. This has been proved.

Disclaimer: HRI is publishing its first online monthly report. The work published in this section represents research activities in the recent past.