
Academic Report (2020-21)



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Research Summary:

We continued our work on topological quantum matter, focussing this year on edge states, Weyl semimetals and also on quasiparticles that occur in these materials as excitations - abelian anyons, non-abelian excitations like Majorana modes and their even more exotic cousins, parafermions.

The work on shining light on bilayer graphene to obtain chiral co-propagating Luttinger liquids at the interface of two polarisations was published. We are now studying the chiral edge states obtained by gating bilayer graphene. In particular, we are looking for reconstruction of these edge states in the presence of electron-electron interactions. We have also been studying the interacting electron system in domain walls in silicene and other spin-orbit coupled materials and in particular, have been trying to see whether we can tune the Kondo effect in the helical Luttinger liquid that is obtained at the domain wall, via gates.

Our work on multicritical points in topological phase transitions was published, as also our work on the interface between $\nu = 3$ and $\nu = 4$ quantum Hall systems. We have continued our work on edge modes and have studied a circuit where the path from the source of electric current to the drain necessarily passes through a segment consisting solely of neutral modes. We find that the neutral modes carry information using which it is possible to reconstruct the DC charge current at the drain. We show that our protocol can be used as a detector of all kinds of neutral modes.

We have also given a new formalism to study anyons in terms of the Kohn-Sham density functional theory, and shown by comparing the theory with exact results from few anyon systems, that it can both qualitatively and quantitatively capture the relevant physics, and may turn out to be a new tool for studying anyons in other contexts as well. We have also been studying parafermion excitations, which can be constructed by the proximity of chiral edge states of quantum Hall systems with superconductors. Our aim is to study detection of parafermions using an Aharonov-Bohm ring setup.

We have studied Fermi arc reconstruction at a junction of two Weyl semi-metals (WSM) twisted by an angle with respect to each other, and shown that there exists regions in the parameter space where the Fermi arcs disconnect from the projections of the Weyl nodes and become normal Fermi loops. These surface states are true surface states and decay exponentially into the bulk. We are also currently studying Weyl semi-metals in a magnetic field in the Hofstadter regime, where the lattice length is comparable to the magnetic length, where we have found not only found new WSM phases we have also found new insulating phases which do not occur in the absence of a magnetic field. Finally, we have also been working on a normal metal - insulator - WSM junction in the thin and thick barrier limits to study electrical conductances and thermal conductances through such junctions.

We have also working on a hybrid setup involving a superconductivity-proximitised quantum spin Hall insulator and a quantum anomalous Hall insulator for chiral injection of electrons. Our aim is to show how to engineer a phase space where the Majorana mode will be stable to disorder and amenable to detection.

Publications:

1. Sourav Biswas, Tridev Mishra, Sumathi Rao and Arijit Kundu, *Chiral Luttinger liquids in graphene tuned by irradiation*, PRB **102**, 235129, (2020).
2. Faruk Abdulla, Priyanka Mohan and Sumathi Rao, *Curvature function renormalisation, topological phase transitions and multicriticality*, PRB **103**, 155428, (2020).
3. Amartya Saha, Suman Jyoti De, Sumathi Rao, Yuval Gefen and Ganpathy Murthy, *Emergence of spin-active channels at a quantum hall interface* PRB **102**, L081401, (2021).
4. Yayun Hu, Ganpathy Murthy, Sumathi Rao and Jainendra Jain, *Kohn-Sham density functional theory of abelian anyons*, PRB**103**, 035124, (2021).

Preprints:

1. Faruk Abdulla, Sumathi Rao and Ganpathy Murthy, *Fermi arc reconstruction at the interface of twisted Weyl semimetals*, cond-mat/2101.09907.
2. Ankur Das, Sumathi Rao, Yuval Gefen and Ganpathy Murthy, *Dc electrical current generated by upstream neutral modes*, cond-mat/2103.06200
3. Vivekananda Adak, Aabir Mukhopadhyay, Suman Jyoti De, Udit Khanna, Sumathi Rao and Sourin Das, *Chiral detection of Majorana bound states at the edge of a quantum spin Hall insulator*, in preparation.
4. Faruk Abdulla, Ankur Das, Sumathi Rao and Ganpathy Murthy, *Lattice Weyl semi-metal in the Hofstadter regime*, in preparation.
5. Sourav Biswas, Allesandro de Martino, Sumathi Rao and Arijit Kundu, *Tunable Kondo effect at domain walls in silicene*, in preparation.

Conference/Workshops Attended:

1. WEB conference, QMAT3 2020, S.N. Bose national centre for basic sciences, Kolkata, India, September 6-11, 2020
2. WEB conference, Emerging trends in quantum matters, statistical and biological physics, Bhubaneswar, India, November 23-24, 2020

Invited Lectures/Seminars:

1. *Edge dynamics of topological phases*, QMAT3 2020, S.N. Bose National centre for basic sciences, Kolkata, 9 September, 2020.
2. *Topological phases of quantum matter*, Online Short term course on current trends in condensed matter physics, NIT, Jalandar, 28 September, 2020.
3. *Topological phases of quantum matter*, Guru Jambheshwar University of Science and Technology, Hisar, Haryana, 16 October, 2020.