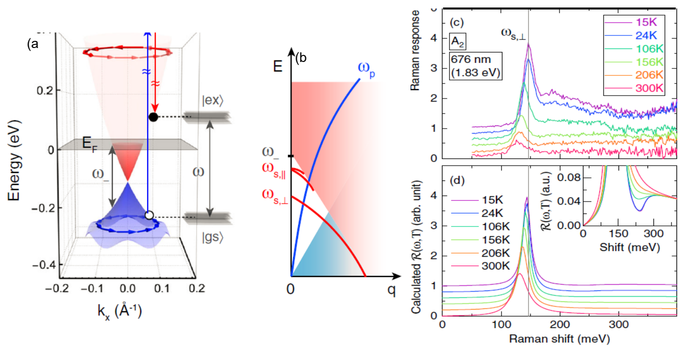
Ph.D. student position will be available, starting in the Fall 2021 / Winter 2022, in the group of Professor Saurabh Maiti

Department of Physics, Concordia University, Montreal, Canada.



Demonstration of application of our theory for collective mdoes applied to topological insulator Bi_2Se_3. (a) Electronic states on the surface of the material. (b) The dispersion of the exotic chiral-spin modes. (c) Experimental data for the intensity of the Raman signal. (d) Theoretical calculation of the Raman intensity. Figures from PRL 119,136802 (2017).

Collective phenomena in low dimensional systems: Broadly my group is interested in understanding the role of various quantum degrees of freedom (arising from orbital, band, valley etc) in the collective response of the system. Studying the collective response helps understand how the quantum materials respond to the experimental probes we use to study their properties. This means that everything we theoretically predict can be directly checked by experiments. This is always exciting.

The systems we are interested in are unconventional superconductors and spin-orbit coupled 2D materials. My group's research theme is based on investigating effects of electronic correlations in various quantum phases of such materials. Our predictions have already been verified in 3 different experiments (see figure) and we look to carry this momentum forward with your help for newer quantum materials. Several projects are open for extremely motivated students at various levels of complexity. One of them is stated below:

Signatures of collective response in doped Graphene:

Electronic properties of Graphene have proven to be quite remarkable. Researchers have demonstrated the physics of strong correlation physics (often attributed to magnets and unconventional superconductors) in twisted bi-layers of Graphene, and have postulated novel ground states with modulated spin or charge density, including chiral superconductivity. The great tunability is made possible via the ability to dope the system by techniques such as gating; via the ability of tuning the number of layers of Graphene, and via tuning the substrate on which Graphene can be grown. While all these possibilities exist, the experimental confirmation of different quantum phases that can exist in various scenarios is often challenging.

We wish to aid the experimental interpretation. We will theoretically study the collective response of the various quantum phases to different perturbations. Given that the strongest response of a system arises from the collective modes of the system and that the response often tends to be very characteristic of the quantum state, it is expected that a sound knowledge of the possible collective

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modes of the system can inform us a great deal about the details of the nature of electronic correlation in the system. Our group has developed techniques to study the collective response of unconventional superconductors, in general, and also understand their Raman spectroscopy signature. We wish to extend such techniques to Graphene systems.

One aspect that adds a characteristic signature to the collective response of any given system is the number of quantum degrees of freedom involved. In superconductivity, this was mostly the spin of the electron. In the case of Graphene systems we have degrees of freedom corresponding to spin, sublattice, valley, and also the number of layers. These added quantum flavors are expected to make the collective excitation phase-space to be rather rich. This is what we wish to explore in this project. We will target mono-layer and bilayer graphene grown on transition metal dichalcogenides (which has a rather unique spin-orbit coupling), and the charge density wave state in Graphene and identify the collective modes of the system and the probes (like Raman scattering) that detect them.

Concordia Department of Physics is a growing department in a university with rapidly increasing rating. We offer research-based M.Sc. and Ph.D. programs. Our faculty members conduct research in the areas of Condensed Matter Physics (theoretical and experimental), Molecular Biophysics, Medical Physics / Imaging, Photonics, Theoretical High Energy Physics, Computational Physics and Physics Education.

Successful applicants will be offered financial packages consisting of RA, TA and various awards of at least 20,000 CAD per year (often more), for 4 years (Ph.D.) or 2 years (M.Sc.). International students will be offered tuition remissions or other awards to compensate for the international tuition fees. Please contact Professor Saurabh Maiti (saurabh.maiti@concordia.ca) or Professor Valter Zazubovits, Graduate Program Director (valter.zazubovits@concordia.ca) for more information.