1 Electron Correlations in Metals and Superconductors

Project description

The undergraduate curriculum in quantum mechanics consists mostly of studies of particles interacting with external potentials. I have in mind a number of projects, generally involving particles (electrons) interacting with one another; this leads to novel states of matter, like superconductivity, magnetism, etc. There are various theoretical approaches, spanning the simplest (quantum mechanics) to the more sophisticated (several many-body formalisms), and projects utilizing either of those will be available. A simple example is a periodic potential with spin-orbit coupling. The presence of spin-orbit coupling in certain lattice types results in exotic phenomena like topological insulators and topological superconductivity. This project will equip a student to understand some of these phenomena in a simple way. Another example is the phenomenon of Anderson Localization due to the presence of defects.

Contact

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2 Superconducting Tc as a function of coupling strength and electron density

Project description

A relatively accurate description of superconductivity exists — the so-called BCS-Eliashberg framework. While some limits exist where analytical work can be performed, most of the relevant parameter space requires numerical calculations. This project will proceed first with the simpler BCS theory; we will compute superconducting Tc as a function of electron density, with particular attention focused on the band edges. Work will be done in both two and three dimensions, since a number of known superconductors are layered. If time permits we will also tackle the more numerically intensive Eliashberg treatment, where retardation effects are explicitly taken into account. The student will begin by examining the current literature. He/she will start with reproducing some known results, both analytically and numerically. Students should be proficient with a computing language (e.g. Matlab, Python, C++, or even Fortran).
3 Search for black holes and string balls with the Large Hadron Collider at the CERN Laboratory in Geneva

Project description

The student will be part of the ATLAS group in the Centre for Particle Physics at the University of Alberta. The group consists of three professors, two postdoctoral fellows, two graduate students and an estimated three summer students. Our group is helping to analyse data recorded by the ATLAS experiment at the Large Hadron Collider near Geneva. My group is studying the possibility of the experiment being sensitive to higher-dimensional space beyond our common three dimensions. String theory is one possible theory that requires higher-dimensional space. For many years, string theory has guided the direction of the "theory of everything". One drawback is that it is extremely difficult to find a unique prediction of the theory that can be testable in current or future experiments. Low-scale gravity and string models based on intersecting D-branes have recently allowed a connection to be made between the theory and experiment. The student will develop the phenomenology of this theory in the context of the ATLAS experiment at the Large Hadron Collider by searching for black holes and highly-excited string states.

The student will perform the computer simulations, analyse and plot data, and present the results. She/he will also document the project and describe the significance of the results. In particular, the student will create an algorithm for searching for evidence of black holes and highly-excited string states at the Large Hadron Collider.

Contact

Prof. Doug Gingrich, gingrich@ualberta.ca
4 Direct observation of transition paths during the folding of RNA pseudoknots

Project description

Description: Our lab recently achieved a long-sought breakthrough in studying how complex structures self-assemble in individual biomolecules: the ability to observe these molecules directly during the brief moments when the structure is assembling. This advance allows to start answering basic questions about how specific structures form. The project involves measuring single RNA molecules that form a structure called a pseudoknot, used by viruses like HIV, SARS, and West Nile virus to change how the information encoded in their genome is read out. The measurements will be done with high-resolution laser tweezers in our labs at NINT, and will tell us about the basic steps involved as the RNA "folds". The applicant will work with a graduate student and senior postdoc, learning to use the laser tweezers to make measurements and then analysing data. Successful results will be incorporated into an eventual publication.

Note: For this project, students may also apply for summer salary support to Alberta Innovates Health Solutions, which has a higher applicant success rate than NSERC. Applications are made via UofA (contact Prof. Woodside for more details).

Contact

Professor: Michael Woodside email: michael.woodside@ualberta.ca

5 Observing position-dependent diffusion along transition paths during biomolecular folding

Project description

The self-assembly of complex structures in biomolecules like proteins, DNA, and RNA is described physically in terms of diffusion in a configurational space. This diffusion is theoretically expected to depend on the position within the space, but it has never been observed directly because of experimental limitations. Due to advances made in our lab in the last year, we are now in a position to address this problem directly. The applicant will work with a graduate student and postdoc to adapt existing theories for application to our experimental data, and then use them to analyse the data. Successful results will form the basis for a publication.
6 Single-molecule studies of misfolding in disease-related mutants of the protein SOD1

Project description

The formation of incorrect, ‘misfolded’ structures by the protein SOD1 is thought cause ALS, a fatal but untreatable neurodegenerative disease. We are able to observe single molecules of SOD1 form such structures when held in laser tweezers. In this project, the student would learn to use the tweezers to measure mutant versions of the protein that are known to cause particularly aggressive forms of the disease, to probe how the misfolding is changed by the mutations and thus attempt to understand the steps that are most important for the disease. Successful results will be incorporated into an eventual publication.

Note: For this project, students may also apply for summer salary support from Alberta Innovates Health Solutions, which has a higher applicant success rate than NSERC. Applications are made via UofA (contact Prof. Woodside for more details).

Contact

Professor: Michael Woodside email: michael.woodside@ualberta.ca

7 Summer Undergraduate Research Experience at CERN in Geneva, Switzerland

Project description

See full details at [http://www.ipp.ca/programs/CERN_summer.shtml](http://www.ipp.ca/programs/CERN_summer.shtml). Students selected for the program will spend from late June to the end of August working with active research groups at CERN, one of the world’s premier international laboratories. Prior to going to CERN, students will work on a subatomic physics project under a Canadian supervisor in May and June so that they will spend a minimum of 15 weeks on research over the course of the summer. IPP researchers across Canada have expressed interest in
taking on IPP summer students for work on a number of potential projects. The May-June period is normally spent in Canada during which time students are supported by the supervisor and an NSERC USRA position or a summer studentship at TRIUMF (see below). IPP will assist students to find a suitable project/supervisor. Students are encouraged to learn about some of the possible projects by visiting the IPP Projects page.

Contact

Prof. Doug Gingrich, gingrich@ualberta.ca