Novel States in 2D Materials and Moiré Structures: Many-Electron Interactions and Topological Effects

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Many phenomena in nature emerge from the interactions of a large number of particles. In reduced-dimensional systems, enhanced electron interactions and topological effects often play a dominant role in determining quantum properties. These effects lead to manifestation of concepts and phenomena that may not be so prominent or have not been seen in the bulk. In this talk, I will present some fascinating quantum phenomena uncovered through theoretical and computational studies of the electronic properties and photophysics of atomically thin one- and two-dimensional materials. Our findings reveal a range of intriguing and unexpected behaviors – such as strongly bound excitons (electron-hole pairs) with highly unusual properties and moiré effects, novel topological phases, prominent correlated three- and four-particle excitations, exciton enhanced nonlinear optical responses, remarkable field-driven time-dependent effects, and correlated excitonic insulator ground states, etc. – adding to the promise of these materials for exploration of new science and valuable applications. Many of these studies were only made possible by the development of new methods, enabling *ab initio* calculations of electronic states, excitonic physics, and photo responses in very large systems and in the time domain.

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