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<u>Friday, March 13, 11:00 am. Osborne A204</u>

Engineering topological quantum magnets in twisted graphene multilayers

Strongly correlated and topological phases in condensed matter systems are at the cutting edge of fundamental physics studies, as well as being promising candidates for the next generation of technological capabilities like quantum computing. In recent years, a remarkable amount of progress has been made in creating and controlling such phases by introducing a small twist angle or lattice mismatch between two dimensional (2D) materials. These systems, called moiré systems, have facilitated the surprising discovery of strongly correlated phases where one might not expect them (e.g. superconductivity in “magic-angle” twisted bilayer graphene) or long-sought new physics (e.g. the fractional quantum anomalous Hall effect (FQAHE) in twisted $MoTe_2$). However, much of the work in this rapidly developing field have focused on the case where the constituent 2D materials of the moiré system are monolayers, or at most bilayers. I will show that this restriction to one or two atomic layers is unnecessarily limiting. Surprising new phenomenology can be realized in graphitic moiré systems, where at least one component is three-layers or more. Most notably, we find that a new type of “moiré enabled” electron crystallization can occur that spontaneously breaks the moiré translational symmetry and has dissipationless edge modes, analogous to a topological version of a Wigner crystal. Our results suggest that these topological electron crystals 1) are at least somewhat common across multilayer graphene moiré systems, 2) can have uniquely tunable magnetization states, and 3) closely compete with the newly discovered FQAHE. Understanding this competition, as well as the novel phenomenology of the topological electron crystal phase, will be of fundamental interest in future studies of strongly correlated topological systems.

Short Bio

Prof. Dacen Waters earned his bachelor’s degrees in physics and mechanical engineering from Arkansas Tech University. He then went on to get his PhD in physics at Carnegie Mellon University, under the supervision of Profs. Randy Feenstra and Ben Hunt. His PhD work focused on two-dimensional material and moiré systems using scanning tunneling microscopy. He then went on to be a postdoctoral fellow in Prof. Matthew Yankowitz’s lab at the University of Washington, where he was awarded a postdoctoral fellowship through the Oak Ridge Institute for Science and Education. At the University of Washington, he utilized transport studies to investigate novel correlated and topological states in graphitic moiré systems. In Fall of 2024, he began as an Assistant Professor in the University of Denver Department of Physics and Astronomy.