Condensed Matter Physics Seminar Series

Going nonlinear with Quantum Materials

Daniel Kaplan
Rutgers

The remarkable success of band theory has revolutionized condensed matter theory and found diverse applications in engineering, electronics and (future) quantum computation. One the salient features of band theory is its description of equilibrium properties, and specifically, the characterization of linear responses to perturbations. In this talk, I will explore a new domain for studying the properties of solids: nonlinear charge response. I will show nonlinear probes of electrons give new information about symmetries and correlations, *beyond* what is accessible in linear responses. Generalizing response theory to collective modes, I will show that structural instabilities in solids are dramatically enhanced through nonlinearities, leading to symmetry breaking and incommensurate phase transitions that – while out of equilibrium – are more robust than their static counterparts. In all these phenomena, I will show the intimate connection with band theory by highlighting the role of quantum geometry in determining nonlinearities, response functions, and the strength of instabilities.

Taking a broad view, I will show geometry is also embedded in the structure of neural networks, as applied to condensed matter problems; I will present a new convolutional neural network approach to the prediction of superconducting instabilities. This has yielded several new superconducting candidates, extrapolated *beyond* the training set of networks. The geometry embedded in “materials space” will be shown to play an important role in the learning carried out by the network.

Daniel Kaplan is a Zuckerman STEM Fellow and Abrahams Postdoctoral fellow at the Center for Materials Theory, Rutgers University. Daniel did his PhD at the Weizmann Institute with Binghai Yan, studying the nonlinear response of magnetic topological materials. At Weizmann, he was a fellow of the Center for Sustainability Research, working on condensed matter applications to technological solutions. He is the inaugural holder of the Zuckerman Scholarship at Rutgers University.
Daniel’s research focuses on the theoretical study of correlations, collective phenomena, and structural instabilities in crystals with particular emphasis on symmetry-guided probes of quantum materials. This has led to new fundamental results in nonlinear optical responses and the latter’s connection to quantum geometry, which were recently probed by several experiments on magnetic topological materials.

Friday, June 6th at 10 AM
4-330 PAB