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Novel electronic degrees of freedom emerging from symmetry breaking of honeycomb lattices

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Electrons are central to the society-transforming information technologies. The intrinsic degrees of freedom of an electron, namely, its charge and spin, have been extensively explored in electronic and spintronic devices. As we are approaching the limit of device miniaturization, the exploration of novel electronic degrees of freedom, in terms of theoretical development and materials discovery, is of current interest. In this talk, we will focus on two strategies to break the symmetry of a Fermionic honeycomb lattice that lead to novel degrees of freedom of Bloch electrons. The essential idea in these approaches is to lift the isospin degeneracy a honeycomb lattice by introducing contrasting identities (chemical or magnetic) to the two sublattices. The new indices of Bloch electrons will then arise, corresponding to contrasting responses to external fields, such as in optical selectivity and anomalous electronic transport. Using combined computational, theoretical and experimental approaches, we go on to demonstrate that the proposed physics can be realized in real material systems. In particular, our results indicate that monolayer transition metal chalcogenides, such as non-magnetic MoX_2 and antiferromagnetic $MnPX_3$ (X = S, Se), can indeed exhibit selective circular dichroism. The associated Berry curvature-supported quantum transport will also be discussed.