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Coupling the valley degree of freedom to antiferromagnetic order

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— Conventional electronics are based invariably on the intrinsic degrees of freedom of an electron, namely, its charge and spin. The exploration of novel electronic degrees of freedom has important implications in both basic quantum physics and advanced information technology. Valley as a new electronic degree of freedom has received considerable attention in recent years. In our paper, we develop the theory of spin and valley physics of an antiferromagnetic honeycomb lattice. We show that by coupling the valley degree of freedom to antiferromagnetic order, there is an emergent electronic degree of freedom characterized by the product of spin and valley indices, which leads to spin-valley dependent optical selection rule and Berry curvature-induced topological quantum transport. These properties will enable optical polarization in the spin-valley space, and electrical detection/manipulation through the induced spin, valley and charge fluxes. The domain walls of an antiferromagnetic honeycomb lattice harbors valley-protected edge states that support spin-dependent transport. Finally, we employ first principles calculations to show that the proposed optoelectronic properties can be realized in antiferromagnetic manganese chalcogenophosphates ($MnPX_3$, X = S, Se) in monolayer form.

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