Emergent spin-orbit phenomena in designer 2D van der Waals materials

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Spin-orbit coupling (SOC)—a relativistic interaction which entangles a particle's motion with its quantum mechanical spin—is fundamental to a wide range of physics phenomena, spanning from the formation of topological insulators to the spin Hall effect of light. Recent years have seen remarkable progress in probing, enhancing and tailoring SOC effects in atomically thin materials and their interfaces. From the electrical control of spin-valley coupling in bilayer graphene [1] to reversible spin-charge conversion in graphene on transition metal dichalcogenides at room temperature [2], these discoveries challenge our previous notions of the possible behaviour of spin-orbit coupled electrons at interfaces. In this talk, I will discuss recent theoretical work aimed to understand the rich interplay of *spin* and *lattice-pseudospin* degrees of freedom afforded by two-dimensional layered materials [3] and report our on-going research on new approaches to control and detect SOC-induced transport phenomena in lateral spin-valve devices [4].

[1] "*Anisotropic spin currents in graphene*", https://physics.aps.org/articles/v11/s108.

[2] M. Offidani, M. Offidani, M. Milletarì, R. Raimondi, and A. Ferreira, "*Optimal charge-to-spin conversion in graphene on transition-metal dichalcogenides*", Phys. Rev. Lett. 119, 196801 (2017).

[3] F. Sousa, G. Tatara, and A. Ferreira, "*Skew-scattering-induced spin-orbit torque at 2D material/ferromagnet interfaces*", Phys. Rev. Res. 2, 043401 (2020); A. Ferreira, "*Theory of spin-charge-coupled transport in proximitized graphene: An SO(5) algebraic approach*", J. Phys. Mat. 4, 045006 (2021).

[4] S. A. Cavill *et al.*, "*Proposal for unambiguous electrical detection of spin-charge conversion in lateral spin valves*", Phys. Rev. Lett. 124, 236803 (2020); A. Veneri, D. T. S. Perkins, C. G. Péterfalvi, and A. Ferreira, "*Twist-Angle Controlled Collinear Edelstein Effect in van der Waals Heterostructures*", Phys. Rev. B Letters (2022).