Graphene is an unusually versatile material allowing us to observe a vast number of quite different effects in the same system. While intrinsic graphene offers both a high electron mobility and long spin lifetime, due to its two-dimensional nature it can easily be modified. For example, proximity coupling to transition metal dichalcogenides (TMD) can increase the spin orbit coupling, or a gate electrode in close contact can induce electrostatic potentials on the nanoscale.

In this colloquium, I will report on our recent experiments on charge and spin transport in graphene. For spin transport, we have demonstrated a spin valve device featuring three-terminal operation where the spin signal can be controlled by a gate voltage. Also, spin-orbit interaction was shown to be increased in TMD/graphene heterostructures, as indicated by a clear weak antilocalization signal. Regarding charge transport, we have focused on high-mobility graphene in a boron nitride/graphene heterostructure. Here the mobility is high enough to allow ballistic transport over at least one micron. Using a periodically patterned few-layer graphene sheet only a few nanometers away, we can impose a 1D or 2D superlattice potential onto graphene.

This is reflected in gate and magnetic field dependent transport in numerous ways. For the 1D superlattices, we observe clear and tunable commensurability oscillations in magnetotransport, while for the 2D superlattices, Hofstadter physics and Brown-Zak oscillations are accessible in a standard lab magnet.