Steering Magnetic Skyrmions with Nonequilibrium Green's Functions

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Magnetic skyrmions, topologically protected vortex-like configurations in spin textures, are of wide conceptual and practical appeal for quantum information technologies, notably in relation to the making of so-called racetrack memory devices. Skyrmions can be created, steered and destroyed with magnetic fields and/or (spin) currents. Here we focus on the latter mechanism, analyzed via a microscopic treatment of the skyrmion-current interaction. The system we consider is an isolated skyrmion in a square-lattice cluster, interacting with electrons spins in a current-carrying quantum wire. For the theoretical description, we employ a quantum formulation of spin-dependent currents via nonequilibrium Green's functions (NEGF) within the generalized Kadanoff-Baym ansatz (GKBA). This is combined with a treatment of skyrmions based on classical localized spins, with the skyrmion motion described via Ehrenfest dynamics. With our mixed quantum-classical scheme, we assess how time-dependent currents can affect the skyrmion dynamics, and how this in turn depends on electron-electron and spin-orbit interactions in the wire. Our study shows the usefulness of a quantum-classical treatment of skyrmion steering via currents, as a way for example to validate/extract an effective, classical-only, description of skyrmion dynamics from a microscopic quantum modeling of the skyrmion-current interaction.