Spintronic Fluctuation Relations

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In quantum mesoscopic transport, higher-order fluctuation relations connect nonequilibrium current–current correlations to nonlinear response coefficients.[1–4] Their form is akin to extented fluctuation-dissipation theorems and they may be derived in some cases from nonequilibrium fluctuation theorems.[5] We investigate the role of a genuine quantum property such as the *spin* degree of freedom in the fluctuation relations.[6] Our motivation is not only fundamental since the electronic spin offers enormous advantages to create devices with unusual and extraordinary new functionalities.

Spins are sensitive to magnetic fields and also to electric fields via spin-orbit interactions. We derive the *spintronic fluctuation relations* when time-reversal symmetry is broken not only by external magnetic fields but also by the presence of ferromagnetic electrodes. We illustrate our findings with a quasi-localized level coupled to helical edge states which are partially polarized by the presence of polarized electrodes. This quantum spin Hall state consists of gapless excitations that exist at the boundaries in which its propagation direction is correlated with its spin due to the spin-orbit interaction.

Moreover, we show that the applicability of nonequilibrium fluctuation theorems when magnetic interactions are present is not *a priori* ensured. We illustrate this statement by using a quasi-localized level coupled to a chiral one-dimensional conducting channels. We demonstrate that local detailed balance condition is not satisfied when a magnetic field is included and the system is driven out of equilibrium. Our formalism is based on zero-frequency fluctuations and time-independent fields but in the presence of arbitrary interactions.

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