Spin current and dc noise generated across biased quantum spin chains

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Spin current refers to a net flow of spin angular momentum through various condensed matter media. While electrical insulators preclude charge currents, spin currents can flow through insulators insofar as the latter support mobile spin excitations. A series of recent experiments have achieved two-terminal spin transport through magnetic insulators [1-4], in which mobile spin excitations, i.e., magnons, carry the spin currents in the insulator bulk, and the injection and detection of spin currents using electrical signals are facilitated by the so-called spin Hall phenomena [5]. These experiments open doors to the fascinating possibility of performing two-terminal spin transport measurements on general quantum spin systems.

Subsequent research efforts have mainly focused on magnetically ordered insulators, whose ground states are *conventional* classical spin configurations with quantum fluctuations generating merely perturbative effects. However, there are a rich plethora of *quantum paramagnets*, which emerge in systems with quantum fluctuations strong enough to destroy any conventional magnetic order and often possess exotic ground states and excitations above them that defy any conventional understanding based on the Landau symmetry-breaking principle. One-dimensional quantum magnets, or quantum spin chains (QSCs), is a great paradigm to study such unconventional quantum magnetism, and the physics of spin transport through these QSCs will be the topic of this talk.

The focus will be on spin transport across two coupled spin-1/2 xxz antiferromagnet chains, with a particular emphasis on the spin current and the dc noise of this current. We consider spin flow induced by simultaneously over-populating spin excitations and elevating the temperature in one sub-system relative to the other. We find a vanishing spin current and a diverging *spin Fano factor*, defined as the spin current noise-to-signal ratio, even in the presence of a temperature bias, as long as an over-population of spin excitations in one sub-system relative to other is absent. We attribute these effects to the underlying fermionic nature of the spin excitations, and compare these results to the case of spin transport across a two coupled magnetic insulators that harness conventional (bosonic) magnon excitations. We address how the spin Fano factor has strikingly different behaviors between the two cases as a function of the population and thermal biases. We finally discuss how the spin Fano factor may be used to extract the so-called spin Hall angle in certain regimes, which can be used to supplement existing methods of characterizing the quantity via ferromagnetic resonance techniques that make use of spin transfer torques acting on the magnetization of a ferromagnetic insulator [5].

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