Spin Noise Spectroscopy

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Magnetic monopoles are hypothetical elementary particles exhibiting quantized magnetic charge $m_0 = \pm(\mathrm{h}/\mu_0\mathrm{e})$ and quantized magnetic flux $\Phi_0 = \pm\mathrm{h}/\mathrm{e}$. A classic proposal for detecting such magnetic charges is to measure the quantized jump in magnetic flux Φ threading the loop of a superconducting quantum interference device (SQUID) when a monopole passes through it. With the theoretical discovery that a fluid of emergent magnetic charges should exist in several lanthanide-pyrochlore magnetic insulators including $Dy_2Ti_2O_7$, this SQUID technique was proposed for their direct detection. Recently, the spectral density of spin-noise $S_\Phi(\omega, T)$ due to fluctuations of $\pm m_*$ magnetic charge pairs were predicted.

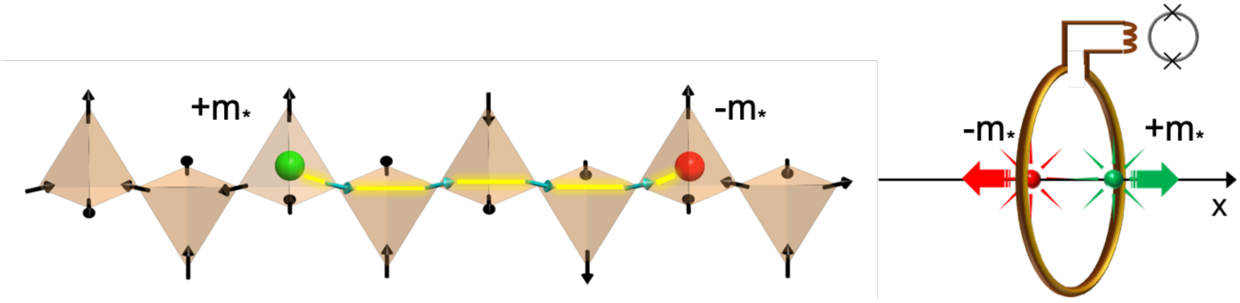

Fig. 2A The sequence of Dy spin flips in $Dy_2Ti_2O_7$ that generate two magnetic monopoles of opposite charge propagating through the material. B) When these monopoles are created within the input coil of a DC SQUID and depart to infinity in opposite directions, the flux through the SQUID jumps by one flux quantum.

In response, Davis' group developed a high-sensitivity, SQUID based spin-noise spectroscopy (SNS) technique, and measured the frequency and temperature dependence of $S_\Phi(\omega, T)$ for $Dy_2Ti_2O_7$ samples. Virtually all the elements of $S_\Phi(\omega, T)$ predicted for a magnetic monopole fluid were detected ([***Nature 531***, 234 (2019)](#)). High precision measurement of the spin-noise spectrum is therefor an innovative approach to magnetic quantum fluids. For MPGCQM our SNS research will be in association with Hidenori Takagi. Spin noise spectroscopy motivates the following projects of immediate interest:

a) We will measure $S_\Phi(\omega, T)$ for $Ho_2Ti_2O_7$ as a function disorder, temperature and eventually magnetic field. This should reveal the magnetic monopole noise of this spin-ice compound.

b) We will study $S_\Phi(\omega, T)$ for CuHTS crystals La_2BaCuO_4 to search for the spin noise associated with disordered and dynamical PDW domains.

c) Magnetic skyrmions are nanometer scale vortices in the texture of spins occurring in magnetic insulators e.g. $Co_7Zn_7Mn_6$. When in liquid phases, few if any techniques are available to determine the arrangement, interactions with environment, and dynamics of skyrmions. We will use flux-noise $S_\Phi(\omega T)$ to study dynamical skyrmions in liquid phases, or while undergoing collective transport, and thus to establish transport theory for skyrmion fluids.