Spin Noise Spectroscopy

J.C. Séamus Davis (Oxford University)
Hidenori Takagi (MPI for Solid State Research, Stuttgart)

Magnetic monopoles are hypothetical elementary particles exhibiting quantized magnetic charge $m_0 = \pm (h/\mu_0 e)$ and quantized magnetic flux $\Phi_0 = \pm h/e$. A classic proposal for detecting such magnetic charges is to measure the quantized jump in magnetic flux $\Phi$ 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$_2$Ti$_2$O$_7$, 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.

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$_2$Ti$_2$O$_7$ 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 therefore 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$_2$Ti$_2$O$_7$ 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$_2$BaCuO$_4$ 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$_7$Zn$_7$Mn$_6$. 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.