Scanned Spin Noise Microscope

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In association with Andrew Mackenzie, Seamus Davis proposes to create and deploy a nm-resolution scanned spin noise microscope SSNM. This unique instrument will connect a nm-scale superconducting input-coil to a DC-SQUID, thus allowing measurement of the time dependence of magnetic flux \( \Phi(t) \) or the flux-noise spectral density \( S_{\Phi}(\omega,T) \) with high spatial resolution. To achieve this objective, we propose to micro-fabricate the pickup coil in a scanned-tip geometry by using focused ion beams (FIB) at the MPI in Dresden. The first-generation pickup coils will then have sub-micron-scale resolution and to plan increased the bandwidth of \( S_{\Phi}(\omega,T) \) of the SSNM to about 2GHz, using an advanced SQUID.

![Fig. 3 The schematic design of the MPGCQM SNNM microscope.](image)

Our experimental objectives for SSNM include:

a) We will use SSNM to visualize the magnetic monopole fluids in Dy\(_2\)Ti\(_2\)O\(_7\) and Hio\(_2\)Ti\(_2\)O\(_7\) as a function disorder, temperature and eventually magnetic field. Below \( T=250\)mK the monopoles freeze, and SSNM will image their conformation to determine if they are constrained by a spaghetti of Dirac-strings connecting each magnetic-charge pair.

b) Both ZnCu\(_3\)(OH)\(_6\)Cl\(_2\) and YbMgGaO\(_4\) are famous candidate materials in which QSL states may occur. However, the former may be magnetically disordered merely due to impurity spins from inter-substitution of Cu at the Zn site, thus mimicking a QSL. A similar situation may pertain in YbMgGaO\(_4\) due to inter-substitution of Mn for Ga. Thus, what is urgently needed is imaging of spin excitations in these QSL candidates by SSNM to reveal their nanoscale heterogeneity or homogeneity. If either is a viable QSL, its fingerprint in the spectral density of spin-noise \( S_{\Phi}(\omega,T) \) will be compared to microscopic QSL theory.

c) Magnetic skyrmions are nanometer scale vortices in the texture of spins occurring in magnetic insulators e.g. Co\(_7\)Zn\(_7\)Mn\(_6\). We plan is to image the flux-noise \( S_{\Phi}(\omega,T) \) of dynamical skyrmions by SSNM, in glassy and especially liquid phases, or while undergoing collective transport, and thus to establish transport theory for skyrmion fluids.

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