Experimental report

03/09/2022

Proposal: 4-02-510 **Council:** 4/2017

Title: Spin-space anisotropy of magnetic excitations in FeSe(1-x)S(x)

Research area: Physics

This proposal is a resubmission of 4-02-492

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Samples: FeSe(0.8)S(0.2)
FeSe(0.85)S(0.15)

Instrument	Requested days	Allocated days	From	To
IN22 CPA	11	10	13/04/2018	23/04/2018

Abstract:

Understanding the microscopic mechanism of superconductivity in iron-based materials is one of the most important quests in condensed matter physics research. While most theories have assumed an insignificant role of spin-orbit coupling, recent ARPES experiments showed that the energy scale of spin-orbit coupling might have been underestimated. In our recent study of FeSe(1-x)S(x) for x=0 and 0.07, we have indeed observed distinct spin-space anisotropy in the low-energy magnetic excitations, which clearly demonstrates that spin-orbit coupling casts a substantial influence on the magnetism, and that the presence of spin-space anisotropy does not require long-range magnetic order. Here, we propose to use spin-polarized inelastic neutron scattering to further pursue the study of spin-space anisotropy of magnetic excitations up to higher sulfur concentrations towards x=0.20, where a nematic quantum critical point may exist, in order to elucidate the relation between spin-orbit coupling, the nematic order, and the optimization of superconductivity.

Experimental Report on "Spin-space anisotropy of magnetic excitations in FeSe(1-x)S(x)"

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Note: this experimental report concerns ILL proposal #4-02-510 as well as CRG proposal 2457. The two experiments were scheduled back-to-back.

The primary goal of the experiment is to investigate the doping evolution of low-energy spin excitations in the FeSe family of iron-based superconductors. The experiment is motivated by the finding that, in FeSe [Ma *et al.*, *PRX* **7**, 021025 (2017)], the spin excitations including the superconducting resonant mode appears to be primarily c-axis oriented in spin space, due to spin-orbit interactions. The scientific question that we are after is to elucidate how such spin-orbit interactions might change their strength with sulfur (lighter element than Se) substitution.

The conclusion of the experiment is the following: With increasing sulfur doping, the contrast of spin-space anisotropy appears to decrease gradually. This is consistent with the notion that the strength of spin-orbit coupling is stronger with heavier element.

A sample of FeSe(1-x)S(x) with x = 0.11 was studied in this experiment. In the tetragonal notation, the low-energy spin excitations are found at (0.5, 0.5, L), and a spin-resonant mode forms at about 4 meV in the superconducting state. Figure 1 displays energy scans performed in three polarization channels, where clear spin-space anisotropy can be observed.

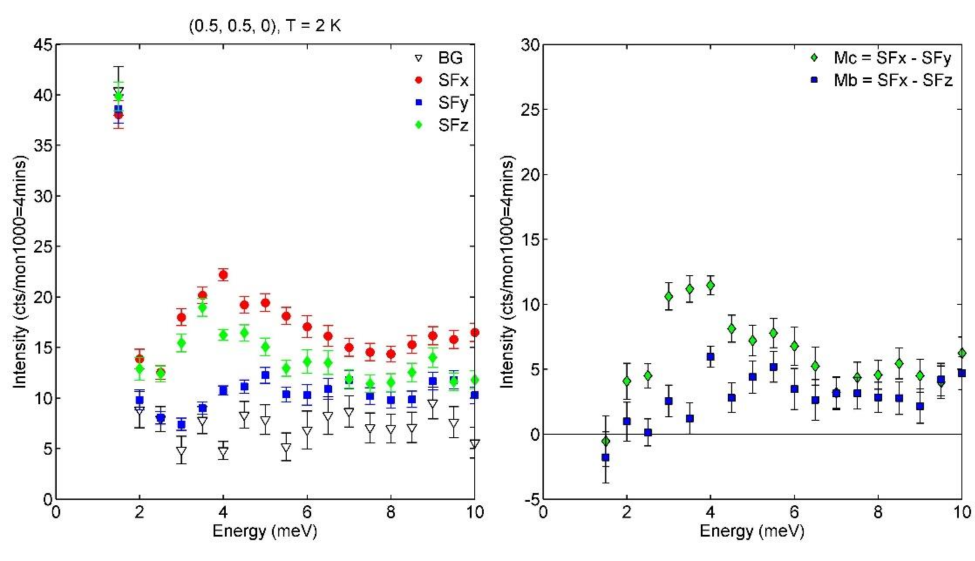

Fig. 1. Energy scans in the superconducting state under different neutron-spin geometries.

Using the background scattering intensity inferred from polarization analysis, we can further obtain the net magnetic intensity at various temperatures, as shown in Fig. 2. In this way, we are also able to compare the spin-space anisotropy to that observed in previous experiments for x=0 and 0.07 samples. It is seen that the low-energy response gradually becomes more isotropic with increasing sulfur doping.

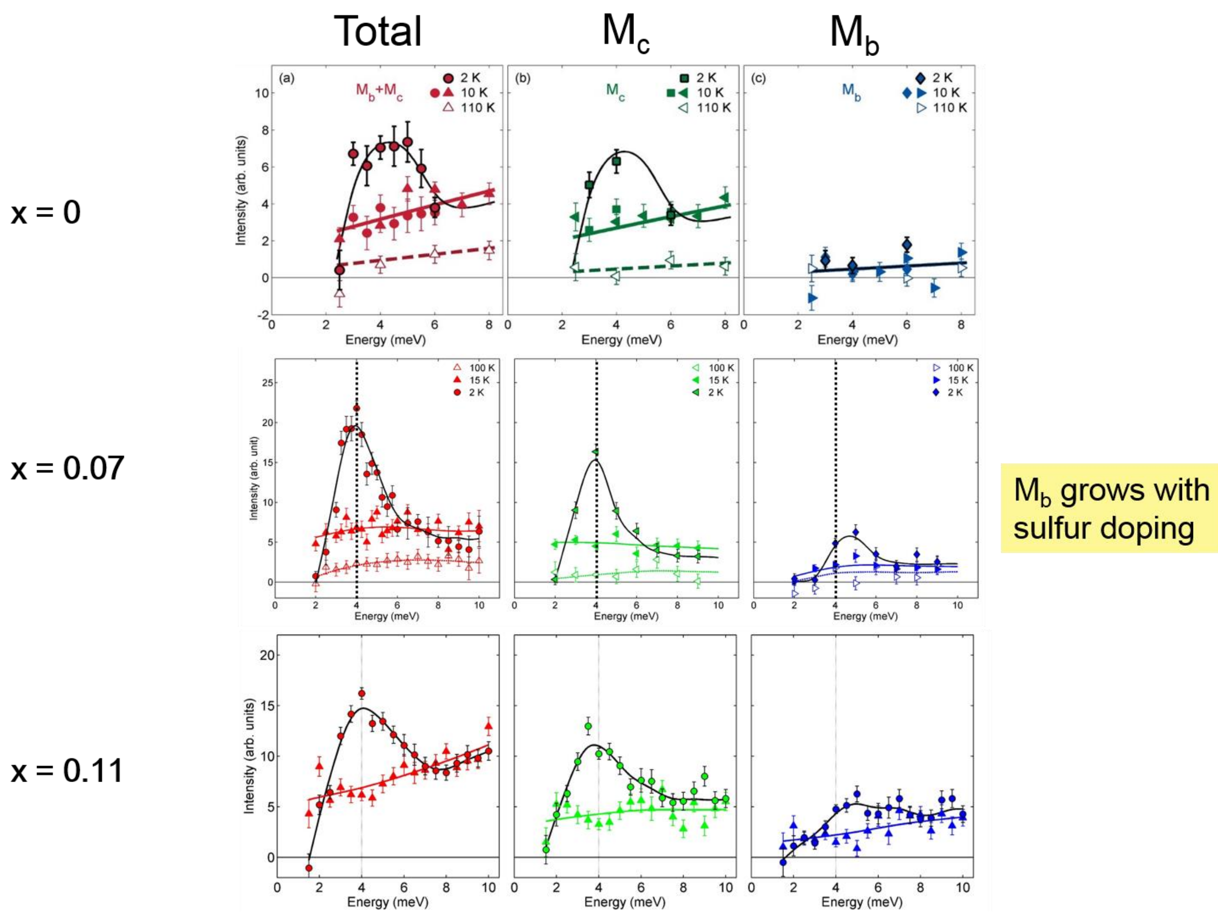

Fig. 2. Doping dependence of spin space anisotropy at different temperatures. The x=0 panels are duplicated from Ma *et al.*, *PRX* **7**, 021025 (2017).

Finally, we have studied the spin-space anisotropy of the resonant peak at 4 meV in the superconducting state, as a function of momentum transfer along c*. The result is displayed in Fig. 3. Such measurements would in principle enable us to tell whether there is a "M_a" component associated with the spin resonant signal. The answer is "probably yes", although the statistics of the measurement data are not good enough to make a firm conclusion.

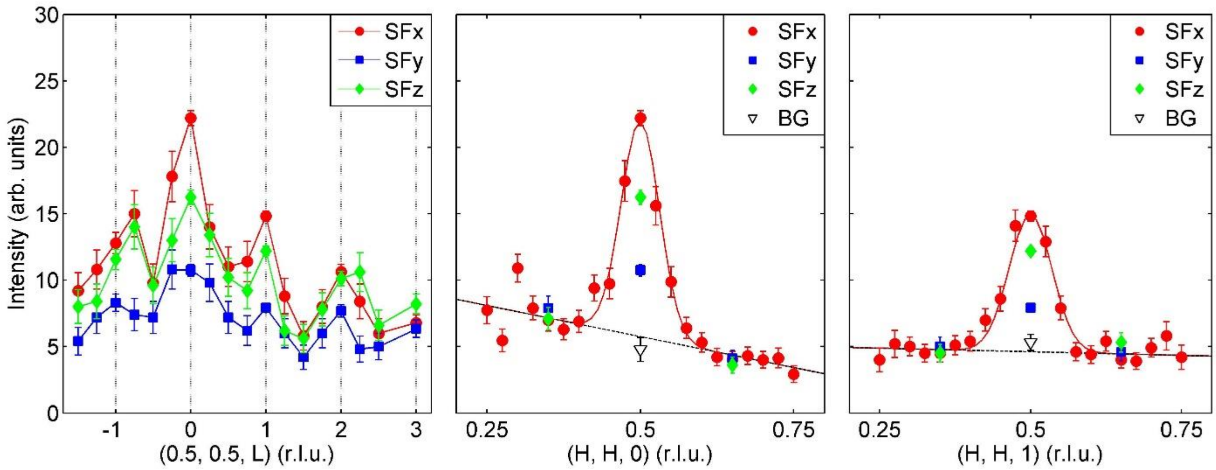

Fig. 3. Polarization analysis on the resonant peak at 4 meV at T = 2 K, measured at different c-axis momentum transfer.