Experimental report

07/02/2020

Proposal: **CRG-2575** **Council:** 4/2018

Title: NATURE OF MAGNETIC FLUCTUATIONS INCO-DOPED SR2RUO4

Research area: Physics

This proposal is a new proposal

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Samples: Sr2Ru0.95Co0.05O4

Instrument	Requested days	Allocated days	From	To
IN22	5	5	24/06/2019	01/07/2019

Abstract:

The most likely pairing mechanism in Sr2RuO4 is based on magnetic fluctuations, but the nature of the relevant fluctuations is still under debate. The most prominent model suggests triplet p-wave pairing to arise from quasi-ferromagnetic correlations. However, as many experiments indicate, Sr2RuO4 is closest to an antiferromagnetic instability. Only recently doping with Co was reported to stabilize ferromagnetic order, which would be the first evidence that Sr2RuO4 is also near a ferromagnetic instability. However, unambiguous evidence for ferromagnetic fluctuations lacks so far and a neutron diffraction experiment is required to unambiguously identify the nature of the magnetic order in Co-doped Sr2RuO4.

Experimental Report

Instrument	IN22
Proposal Number	CRG-2575
Proposal	Nature of magnetic fluctuations in Co-doped Sr_2RuO_4
Experimentalist	Kevin Jenni, Yvan Sidis, Agung Nugroho, Markus Braden
Local Contact	Wolfgang Schmidt

The characterization of magnetic fluctuations in Sr_2RuO_4 is crucial for understanding the super-conducting pairing mechanism since different symmetries of the superconducting pairing are connected to different types of magnetic fluctuations. It has been shown that in Sr_2RuO_4 strong antiferromagnetic (AFM) fluctuations exist originating from nesting as well as broad and weaker ferromagnetic (FM) fluctuations [1,2]. Doping with Ti and Ca leads to static ordering of this AFM instability, which emphasizes the proximity of Sr_2RuO_4 to the AFM fluctuations. It has been reported that doping with small amounts of Co induces static short-range FM order seen in the steep increase of remnant magnetization with decreasing temperature as well as the magnetic hysteresis [3].

We recently succeeded to grow large single crystals with 1.5 % and 5 % Co content in our institute and wanted to investigate the origin of these FM footprints in the magnetization by neutron scattering. Therefore we measured different elastic Q scans around the incommensurate (IC) position (0.7 0.3 0) and equivalent positions at temperatures in phase (1.6 K) and out of phase (30 K) to look for any static order occurring. We analyzed two samples with different Co content (1.5 and 5 %). Fig.1 shows exemplary data of the 5 % Co doped sample. The scans in Fig.1 (a)-(h) indicate no signal appearing at low temperatures. There is no spin-density wave (SDW) forming at the AFM position as seen in the Ca and Ti doped compounds. Also around the FM position (1 0 0) no temperature dependent differences can be identified (Fig.1 (i)-(k)). Some single spikes are present, which show no temperature dependence and are therefore most likely of spurious origin or due to higher order contamination. Similar data was recorded for the 1.5 % Co doped sample and there no static order was found as well.

While there is no localized magnetic intensity detectable around the usual Q vectors, one could notice a small increase of signal in the longitudinal scans around (0.3 $\pm$0.3 0) to smaller Q vectors at low temperatures (Fig.1 (b)+(d)). During the final heat up in the end of the experiment we made a three-point scan close to the IC position (0.3 0.3 0) at various temperatures (Fig.2). The signal increases below 30 K while the gain is smallest at the IC position. The temperature dependence of the signal at this low Q vectors is consistent with the squared susceptibility we obtained by SQUID measurements. Unfortunately the limited beamtime did not permit to fully characterize this signal. The magnetic intensity was not detected at equivalent positions with higher Q vectors but appears only at lowest Q. The Q dependent magnetic form factor falls off rapidly for Ru, which makes this signals hard to detect around higher Q vectors.

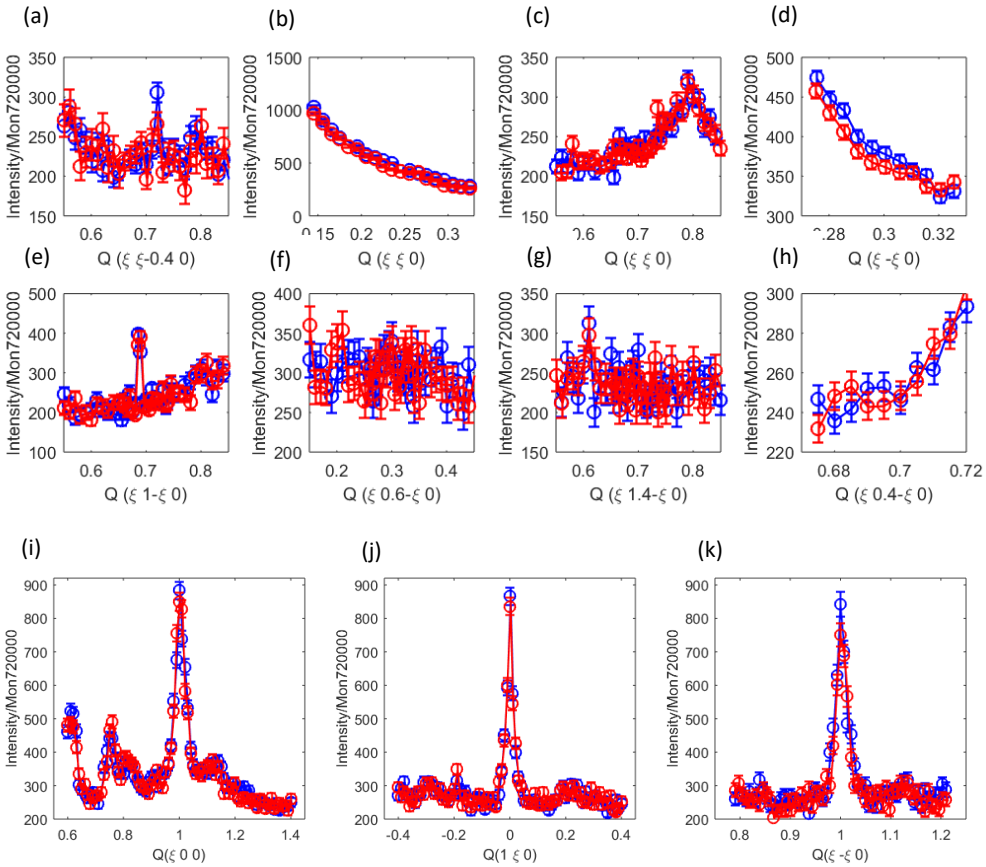

Fig. 1: Elastic Q scans around the IC positions (a-h) and FM position (1.6 K in blue, 30 K in red).

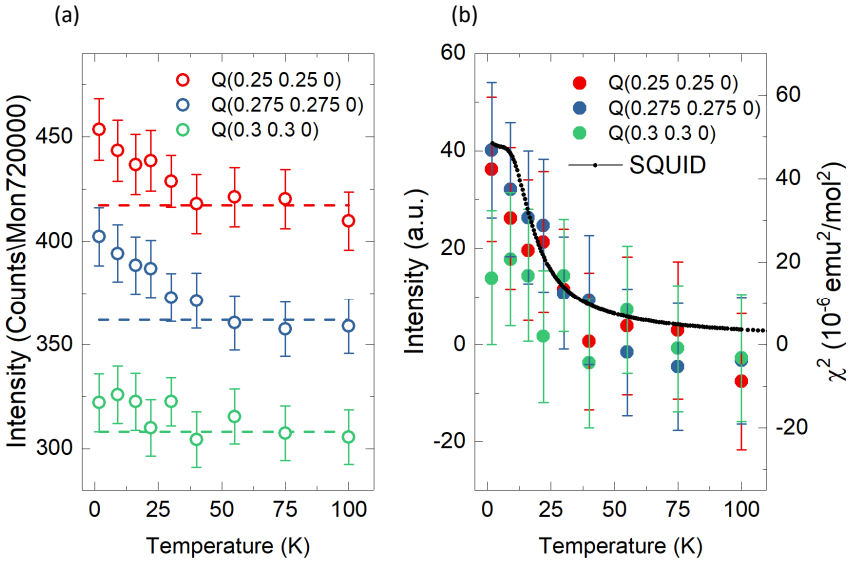

Fig. 2: Temperature dependence of different Q points. In (b) the constant background (from (a)) is subtracted and compared with the squared susceptibility measured by SQUID.

Beside the search for static order we investigated also the inelastic response of the IC signal at (0.7 0.3 0) as it has been done for the pure compound [1]. Indeed we found the inelastic signal in both compounds with different Co doping (Fig.3). The energy dependence is not doping dependent and resembles the energy dependence of the IC signal in the pure compound with its peak around 8 meV. The Co doping does not affect the AFM spin fluctuations.

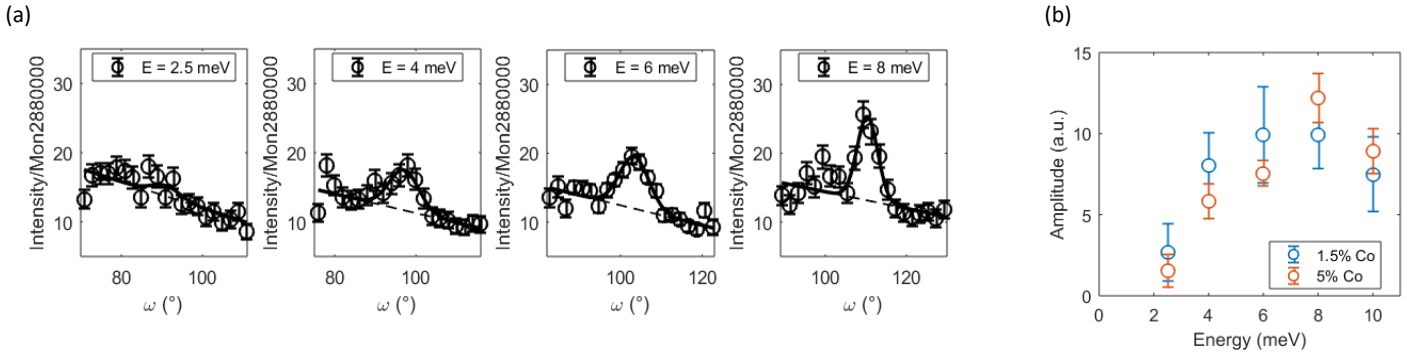

Fig. 3: (a) Rocking scans at Q(0.7 0.3 0) at different energies for 5 % Co doping. (b) Energy dependence of the IC signal for both Co dopings.

We can conclude that the FM footprints in the magnetization of Co doped Sr_2RuO_4 do not arise from a SDW order or static FM order. The only elastic temperature dependent signal is visible at low Q in the proximity of (0.3 0.3 0), but does not appear around equivalent large Q positions. This finding needs further investigation. The AFM spin fluctuations are not influenced by the Co doping shown by the inelastic neutron scattering data. This is consistent with the non-existence of SDW ordering.

References

[1] Y. Sidis et al., Phys. Rev. Lett. 83, 3320 (1999). M. Braden et al., Phys. Rev. B 66, 064522 (2002); M. Braden et al., Phys. Rev. Lett. 92, 097402 (2004).
[2] P. Steffens, Y. Sidis, J. Kulda, Z. Mao, Y. Maeno and M. Braden PRL 120, 047004 (2019).
[3] J. E. Ortmann et al., Sci. Rep. 3:2950 (2013).