

# Experimental report

12/09/2023

**Proposal:** 4-02-615

**Council:** 10/2022

**Title:** Searching for superconductivity-feedback effect in the FM and AFM spin excitation channels of YFe<sub>2</sub>Ge<sub>2</sub> single crystals

**Research area:** Physics

**This proposal is a new proposal**

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**Samples:** YFe<sub>2</sub>Ge<sub>2</sub>

Instrument	Requested days	Allocated days	From	To
ORIENTEXPRESS	1	1	04/04/2023	05/04/2023
THALES	7	6	05/04/2023	11/04/2023

## Abstract:

Ferromagnetic and antiferromagnetic spin fluctuations tend to mediate superconducting pairing with different symmetry. Elucidating the spin fluctuations in unconventional superconductors are thus crucial for understanding the pairing mechanism. In contrast to the widely-studied AFM fluctuations, FM fluctuations are largely unexplored due to the limited candidate compounds. Our recent inelastic neutron scattering measurements revealed the coexistence of in-plane FM and stripe-type AFM spin fluctuations in a newly-discovered iron germanium superconductor YFe<sub>2</sub>Ge<sub>2</sub>. The single crystals are further fabricated to be bulk superconducting, thus providing great opportunity to study the superconductivity feedback effect on both spin excitation channels in this compound, among which the spin resonance mode would be a prototype. Our results will shed new light on the interplay between superconductivity and ferromagnetic fluctuations together with antiferromagnetic fluctuations.

## Experiment report for 4-02-615

### Scientific Background

Elucidating the nature of spin fluctuations is important to determine the pairing mechanism of unconventional superconductors. Ferromagnetic (FM) fluctuations tend to mediate  $p$ -wave triplet pairing and introduce pair breaking for singlet superconductivity, while antiferromagnetic (AFM) fluctuations behave in an opposite manner. Enormous previous research efforts have been made on studying AFM spin fluctuations in cuprate, iron-based and heavy-fermion superconductors [1-3], where a spin resonance mode is commonly observed in the AFM spin fluctuation spectrum, suggesting a sign-reversed singlet pairing. By contrast, although FM spin fluctuations and the corresponding spin-triplet pairing have great significance not only in the fundamental science but also in the frontier technology including superconducting spintronic and quantum computation [4-6], they are largely unexplored due to the limited candidate compounds and the lack of evidence for strong coupling between FM spin excitations and the superconductivity [7].

Our recent inelastic neutron scattering measurements have revealed the coexistence of in-plane FM and stripe-type AFM spin fluctuations in the normal state of a newly-synthesized iron germanium superconductor  $\text{YFe}_2\text{Ge}_2$  [8] (Fig. 1).  $\text{YFe}_2\text{Ge}_2$  therefore becomes the first iron-based superconductor in which ferromagnetic spin fluctuations are observed by inelastic neutron scattering experiments, providing a great opportunity to study the interplay between superconductivity and ferromagnetic fluctuations together with antiferromagnetic fluctuations.

### Experiment Results

The superconductivity of  $\text{YFe}_2\text{Ge}_2$  is extremely sensitive to defects/disorders, and fabricating bulk superconducting  $\text{YFe}_2\text{Ge}_2$  single crystals is not trivial [9]. Recently, we have successfully synthesized high-quality single-crystalline  $\text{YFe}_2\text{Ge}_2$  using the chemical vapor transport method. The single crystal exhibits bulk superconductivity with very high residual resistivity ratio (RRR)  $\rho(300\text{K})/\rho(2\text{K}) \sim 300$  (Fig. 2(b)). As illustrated in Fig. 2(b) and (c), a sharp superconducting transition can be verified in resistivity and ac susceptibility measurements. The heat capacity also shows a clear jump (Fig. 2(d)), which signals the bulk superconductivity.

In this experiment, bulk-superconducting  $\text{YFe}_2\text{Ge}_2$  single crystals with a total mass of 10 grams were co-aligned in the  $(H, 0, L)$  scattering plane (Fig. 2(a)). The sample assembly was mount on dilution refrigerator stick. The DR insert enables us to reach the base temperature below 0.1 K and to control the temperature continuously. Single detector configuration was adopted on ThALES with  $E_f = 5$  meV. The feedback effect of superconductivity in the low energy spin excitations has been carefully searched for. Interestingly, there is a noticeable transfer of spectral weight across  $T_c$  (Fig. 3), resembling the spin resonance modes frequently observed in unconventional superconductors. Our results suggest a strong interplay between superconductivity and spin fluctuations in  $\text{YFe}_2\text{Ge}_2$ , while a detailed temperature evolution and the origin of the relatively weak resonance signals is still elusive. A continuation submission will be

our future plan to address these remaining concerns.

## References

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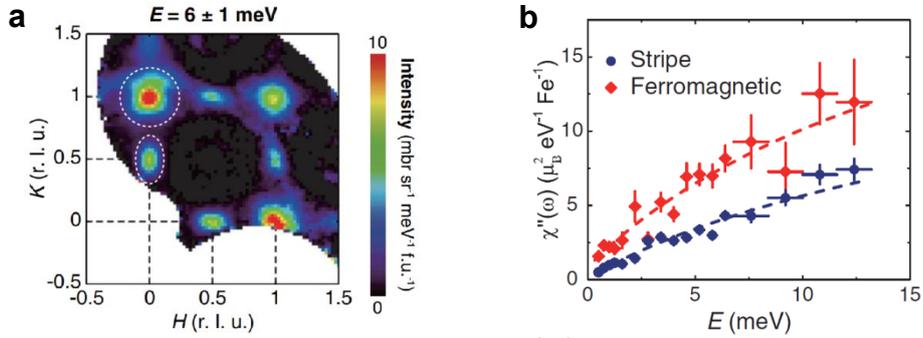


Fig. 1 (a) A contour plot of the spin excitations in the  $(H, K, 0.5)$  plane (1-Fe notation) in  $\text{YFe}_2\text{Ge}_2$  at 4 K, with FM and stripe spin fluctuations indicated by dashed circle and ellipsoid respectively. (b) Momentum-integrated local susceptibility in  $\text{YFe}_2\text{Ge}_2$ . Fig. 1 is adopted from Ref. [8].

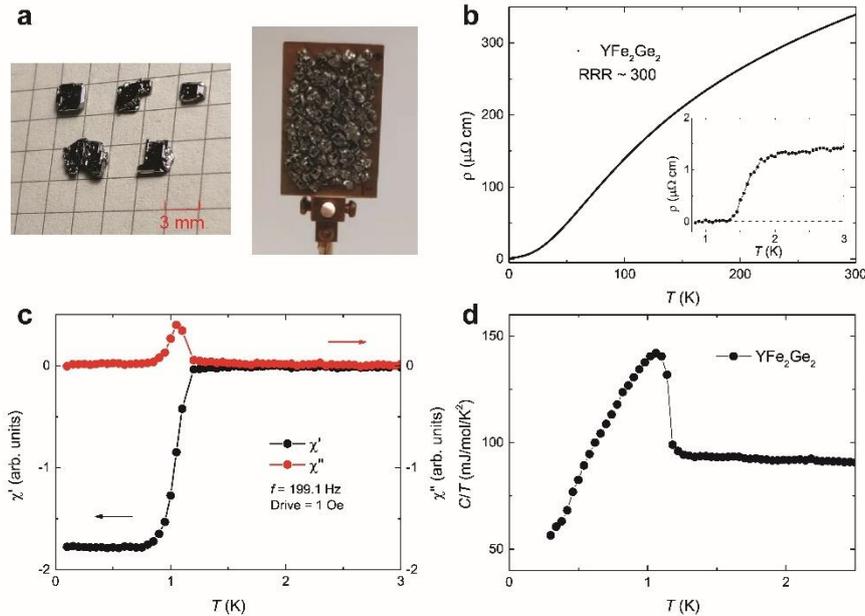


Fig. 2 (a) Photo of the  $\text{YFe}_2\text{Ge}_2$  single crystals (left) and the sample co-alignment assembly (right). (b-d) The resistivity, ac susceptibility and heat capacity in  $\text{YFe}_2\text{Ge}_2$

around the superconducting phase transition, demonstrating the high quality of the sample and its bulk superconductivity.

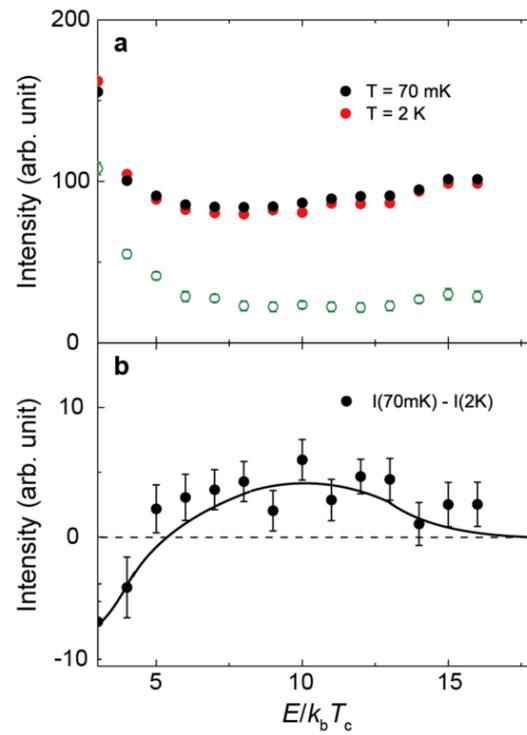


Fig. 3 Overplot (a) and difference (b) of energy scans below and above  $T_c$ . The background signals are presented by green dots. The results suggest a feedback effect of superconductivity on spin excitations in  $\text{YFe}_2\text{Ge}_2$ .