Experimental report

02/09/2022

Proposal: **4-03-1737** **Council:** 4/2019

Title: Spin Waves and Magnetic Exchange Couplings in Ferromagnetic LaCrGe3

Research area: Physics

This proposal is a new proposal

Main proposer: **Kelly NEUBAUER**

Experimental team: Kelly NEUBAUER
Yaofeng XIE
Alexandre IVANOV
Philippe BOURGES

Local contacts: Alexandre IVANOV
Stephane RAYMOND

Samples: LaCrGe3

Instrument	Requested days	Allocated days	From	To
THALES	0	4	24/06/2021	28/06/2021
IN12	7	0		

Abstract:

Recent studies of LaCrGe3 illustrate a unique wing-structure phase diagram and a new magnetic phase tunable by thermodynamic parameters. While transport studies have strongly supported this phase diagram, the precise nature of transitions remains unknown. In particular, the order of the paramagnetic to ferromagnetic (FM) phase transition and the FM1 to FM2 metamagnetic phase transition needs to be clarified. To determine this, we propose an inelastic neutron scattering experiment to study the low energy spin waves and exchange coupling interactions across the phase transitions of LaCrGe3. We will map out the temperature dependence of the spin wave dispersion to determine the exchange coupling along different directions across the phase transitions. By determining the exact nature of this critical phase transition phenomena, we will help to fully explain the magnetic state of LaCrGe3 and improve the understanding of novel behavior related to quantum phase transitions.

Report on the proposal (4-03-1737)

Title: Spin Waves and Magnetic Exchange Couplings in Ferromagnetic LaCrGe3

Experimental team: Philippe Bourges, Kelly Neubauer, Pengcheng Dai, Su Yixi,

Abstract: In the proposal 4-03-1737, we planned to study the temperature dependence of the spin wave dispersion. Previous transport measurements indicated interesting critical phase transition phenomena as a function of temperature and pressure in the LaCrGe3 system. It was important to use neutrons to clarify the nature of the phase transition at zero-pressure to support further research on this system. The experiment showed that the system actually has an antiferromagnetic contribution whose presence forms the phase boundary previously observed in transport.

Studies of quantum phase transitions have led to new understandings of novel properties such as superconductivity, non-Fermi liquid behavior, and tri-criticality and influenced innovative industrial and technological applications [1,2]. LaCrGe3 is a hexagonal system with ferromagnetic ordering below TC = 86 K [1]. Recent studies propose a unique wing-structure phase diagram with triciritical wings that emerge as a function of temperature, pressure, and magnetic field [1,3]. Transport measurements propose the existence of two magnetic states, FM1 and FM2 near 70K [4-5]. The exact nature of this phenomena remains unknown, calling the need for neutron studies to develop a deeper understanding of the magnetic phase transitions in this system. For this reason, we performed neutron scattering measurements at THALES. From our measurements, we were able to clarify the relationship between the transport phenomena, magnetic structure, and spin dynamics attributing the FM1-FM2 phase transition to an AFM contribution.

On THALES, the LaCrGe3 sample was mounted in the H0L scattering plane to access various Bragg peaks including (1,0,0) and (1,0,1). We used a standard cryostat to access temperatures from 5-300K. The order parameters of (1,0,0), a ferromagnetic Bragg peak, and (1,0,1), an antiferromagnetic Bragg peak, were measured (Fig. 1) with the (1,0,1) peak showing anomalous behavior distinct from ferromagnetism. Instead a weak antiferromagnetic moment was shown to emerge at the FM1-FM2 boundary observed in previous transport measurements.

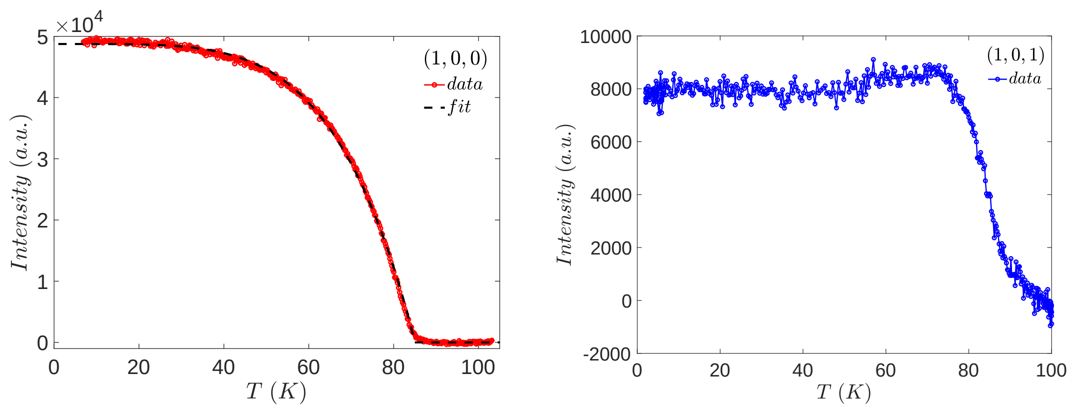

Fig. 1. Order parameters of (1,0,0) and (1,0,1) Bragg peaks.

Additionally, we measured the spin wave dispersion to see determine if the nature of the FM1-FM2 transition is also coupled to magnetic exchange couplings in addition to the magnetic state. We focused on the (1,0,0) position and measured the spin dispersion along the H and L directions as a function of temperature. A gap was observed and determined to be 1.21 meV at 5 K. The dispersion along H was observed steeper than the dispersion along L. No sharp anomaly was observed in the temperature dependence of the spin wave dispersion corresponding to the FM1-FM2 boundary.

This experiment clarified the FM1-FM2 transition, which we contribute to the presence of a small AFM component. This helps us understand previous transport measurements and provide a basis from which further research can be performed on this system. In particular, fully understanding the zero-pressure behavior of this compound will help us understand the complex phase transitions observed under pressure.

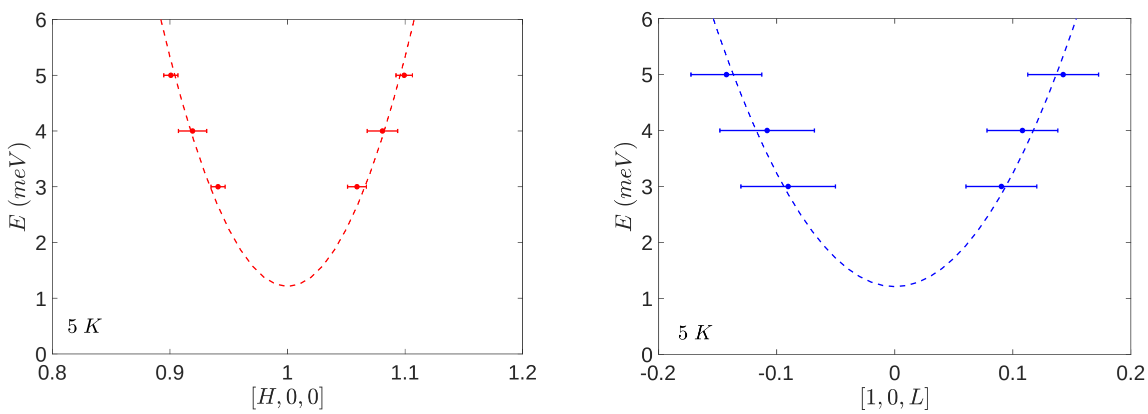

Fig. 2. Spin wave dispersions along [H,0,0] and [1,0,L] at 5K.

References:

[1] V. Taufour et. al, Physica B 536, 483-487 (2018).

[2] M. C. Nguyen et. al, Phys. Rev. B 97, 184401 (2018).

[3] U. S. Kaluarachchi et. al, Nat. Commun. 8, 546 (2017).

[4] V. Taufour et. al, PRL 117, 037207 (2016).

[5] V. Taufour et. al, PRL 105, 217201 (2010).