Experimental report

30/08/2022

Proposal: **4-01-1697** **Council:** 10/2020

Title: Field-induced phases and magnetisation plateau in Er2Si2O7

Research area: Physics

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Samples: Er2Si2O7

Instrument	Requested days	Allocated days	From	To
IN5	5	4	25/06/2021	30/06/2021

Abstract:

We propose to investigate the excitations spectrum of the D-type Er2Si2O7 antiferromagnet in an applied magnetic field. Below the ordering temperature, T_N = 1.8 K, this compound with a distorted honeycomb lattice orders into a 4-sublattice antiferromagnetic structure. For a magnetic field applied along the a-axis, magnetisation at low temperatures shows a narrow, but clearly visible plateau at about a third of the saturation value. The origin of the plateau is currently unknown, however its stabilisation is accompanied by a significant increase of the magnetic unit cell. Our recent neutron diffraction experiments showed that new, non-integer magnetic peaks indexed as (0, k+1/2, l+1/2), (0, k+1/3, l) & (0, k+2/3, l), where k and l are integers, appeared in a narrow range of an applied field. Apart from determining the effective Hamiltonian of the system from the zero field-measurements, we are particularly interested in seeing how the excitation spectrum is affected by a transition into a plateau phase.

$Er_2Si_2O_7$ IN5 Experiment - June 2021

The chemically complex rare-earth disilicate, $Er_2Si_2O_7$, forms three different crystalline polymorphs. The D-type has a $P2_1/b$ space group, with the magnetic Er^{3+} ions arranged in distorted honeycomb layers, stacked along the *a* axis [1]. Initial magnetic properties studies by Leask *et al.* suggest a four-sublattice antiferromagnetic ground state below the ordering temperature of 1.9 K [2]. This has been directly confirmed via powder diffraction measurements. The highly isotropic magnetisation curves were understood by the use of simple Monte-Carlo simulations however, the presence of a magnetic plateau at 1/3 of the magnetic saturation, shown in Figure 1, disagreed with the theoretical model.

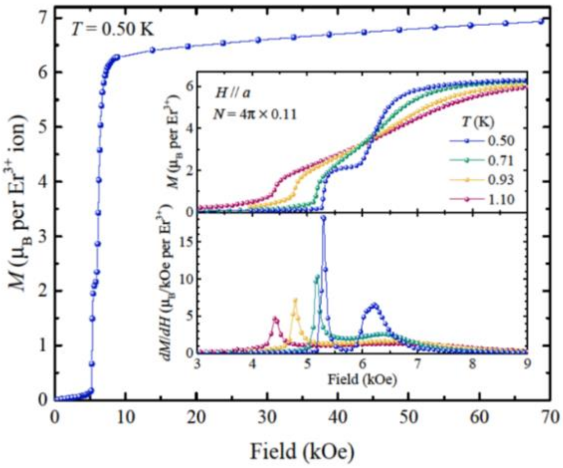

Figure 1: Field dependence of $Er_2Si_2O_7$ for $H \parallel a$ at 0.5 K. The inset details the transition at 5.3 kOe and the effect of temperature (top panel) on the magnetisation, *M*, and the field derivative d*M*/d*H* (bottom panel). A demagnetisation factor of N_a = 0.11 x 4π.

A magnetic 1/3 plateau is usually associated with spin-frustrated and low-dimensional magnets and so is considered unusual for a four-sublattice structure. It was suggested in [2] that an increase in the magnetic unit cell could be an explanation however, this was dismissed as unlikely.

Our previous single crystal neutron diffraction measurements on WISH, ISIS reveal a significant increase in the size of the magnetic unit cell during this plateau. The applied field associated with the magnetic plateau induces a dramatic change in the diffraction pattern. Non-integer magnetic peaks indexed as (0, k + 1/2, l + 1/2), (0, k + 1/3, l) and (0, k + 2/3, l), where k and l are integers, appear only during the narrow plateau region.

Figure 2: Single crystal of $Er_2Si_2O_7$ on a copper mount with (*hk*0) horizontal.

Currently, there is no information on the strength of the magnetic interaction in D-type $Er_2Si_2O_7$. The experiment was thus performed to determine an effective Hamiltonian of the system using neutron diffraction measurements in zero field. The effect on the excitation spectrum during the transition into the magnetic plateau phase was also of great interest.

As shown in Figure 2, a large single crystal sample of $Er_2Si_2O_7$ was aligned on a copper sample holder with the (*hk*0) axis horizontal. Measurements were taken with a wavelength of 4.8 Å, a wavelength of 6.5 Å was also tested but there was no significant improvement compared to the lower resolution. A ^{3}He dilution refrigerator was used to reach the ordering temperature of 1.8 K as a regular cryostat would be insufficient. Access to lower temperatures was also crucial for the stability of the plateau, as seen in Figure 1. The applied field ranged from 0kOe and 10 kOe at 45 mK, with a sample rotation of 30 degrees to check for the plateau peaks. Full scans of 120 degrees were performed at 0, 6 and 7 kOe.

The main results of the experiment are presented in Figure . The non-integer peaks associated with the magnetic plateau region were found and used to navigate the magnetisation curve of the sample. The evolution of the powder averages in-field is shown as the 1/3 plateau is reached and surpassed. Flat, dispersionless excitations were found with no significant dependence of the intensity on the scattering vector. The evolution of the plateau with temperature was also investigated. Additional 30 degree scans and powder average at 6 kOe were taken at temperatures of 0.5, 1, 1.8 K and are shown in Figure 4. The excitations were shown to be temperature sensitive, and disappear when the ordering temperature is reached. We are now in the process of mapping these excitations and their evolution with field and temperature. We are also aiming to theoretically model the magnetic interactions in field.

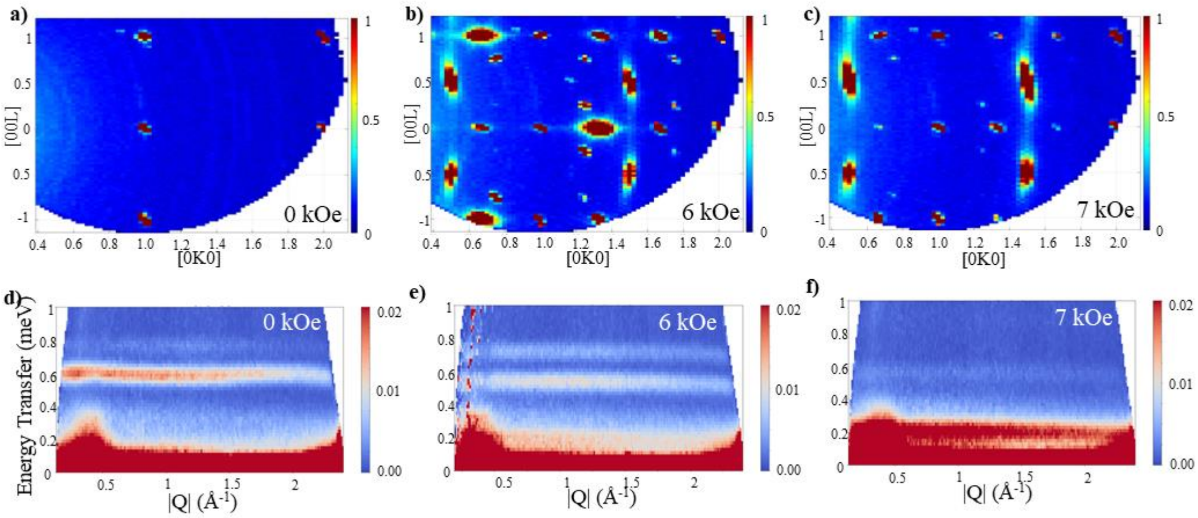

Figure 3: Evolution of the powder averaged energy spectra using the IN5 spectrometer on a single crystal sample of D-type $Er_2Si_2O_7$ at *T* = 0.045 K with applied field. The sample was rotated in the direction of the applied field *H* || *a*, while the powder average was taken in the *b** - *c** scattering plane.

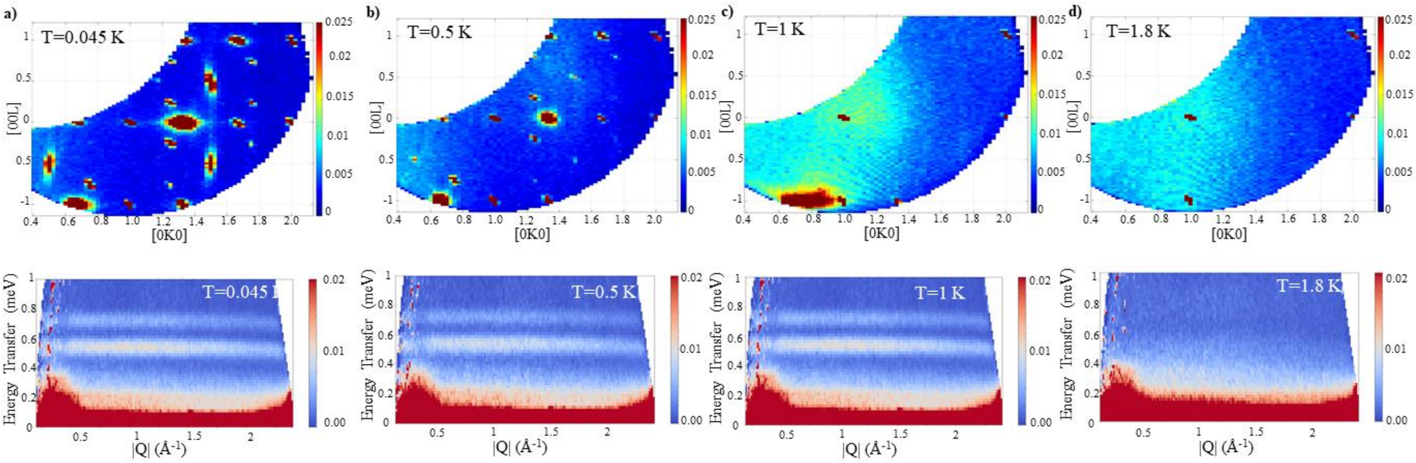

Figure 4: Evolution of powder averaged energy spectra using the IN5 spectrometer on a single crystal sample of D-type $Er_2Si_2O_7$ at *H* = 6 kOe with temperature. The sample was rotated in the direction of the applied field *H* || *a*, while the powder average was taken in the *b** - *c** scattering plane.