Anisotropic magnetic properties of $DyAl_3(BO_3)_4$ single crystals

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Studies of fundamental magnetic properties, in particular of the low-temperature magnetic phase transition, of the $DyAl_3(BO_3)_4$ single crystals are presented.

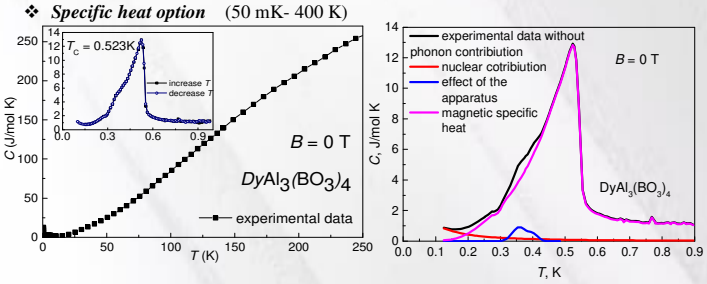
Measurements were performed for various orientations of magnetic field with respect to the crystallographic axes. It was found that the temperature of this transition decreases under influence of increasing external magnetic field. A sharp λ-type anomaly of specific heat is associated with the onset of a magnetic ordering at T_c = 0.523K, in agreement with magnetic measurements. The shape of the *M vs T* and *M vs H* curves indicates the existence of a canted state, with the main component of the magnetic moment along the c axis. A metamagnetic transition manifests itself below T_c in the *M vs H* curve for *H* applied perpendicularly to the *c*-axis. It was concluded that the magnetic behavior of the compound studied seems to be very rich, both in the static properties with a complex magnetic ordering, and the field induced transition, when the field is applied perpendicularly to the *c*-axis, and in the dynamic properties with a complex behavior of the *ac* susceptibility.

The phase diagram of dysprosium aluminoborate was constructed for 50 mK ≤ T < 2 K based on neutron diffraction, dc magnetization, and ac and dc magnetic susceptibility data, as well as on thermal expansion and specific heat measurements performed in the function of temperature and magnetic field.

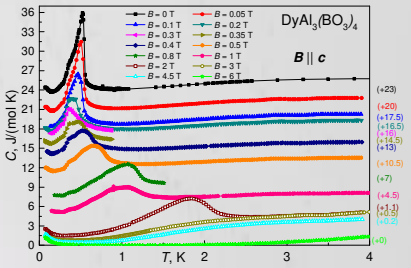
Specific heat studies

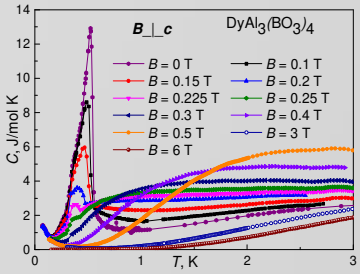
9T magnet PPMS system equipped with

- ***Dilution Refrigerator (DR) option*** (minimum temperature 50 mK)
- ***Specific heat option*** (50 mK- 400 K)



$$C_{total} = C_m + C_{ph}(T) + C_{nuclear}(T) + C_{Schottky}(T)$$





Evolution of the specific heat anomaly, related to the magnetic phase transition, in the magnetic field *B* parallel and perpendicular to the *c* axis.

On increase of the external magnetic field parallel and perpendicular to the ***c*** -axis, there were observed:
- lowering the transition temperature, - damping the λ anomaly,
- appearance of a wide maximum shifting towards higher temperatures

The sharp λ-type anomaly of specific heat at $T_C = (0.523 \pm 0.2)$ K accompanies **the second order magnetic phase transition:**

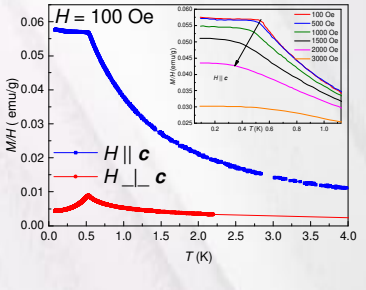
► **no hysteresis** ► **lambda-like shape**

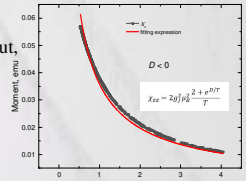
We interpret it as the appearance of a long range ordering of Dy^{3+} magnetic moments.

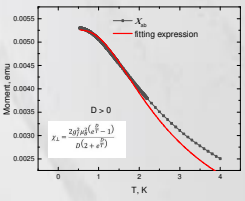
Magnetic measurements

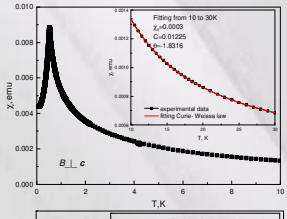
High-field low temperature SQUID-magnetometer

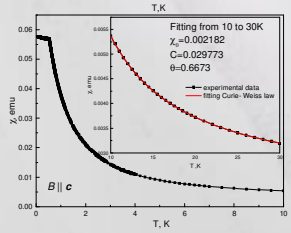
- with DR option developed at the Néel Institut, CNRS (temperature down to 75 mK)
- magnetic field up to 8.5T

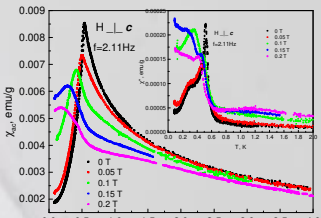


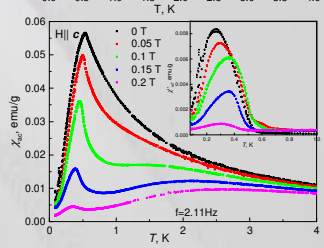


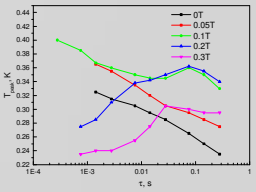


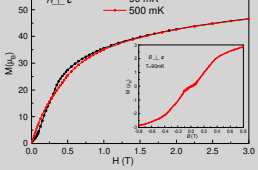












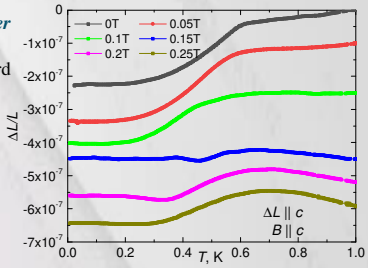
Magnetization process at 90 mK

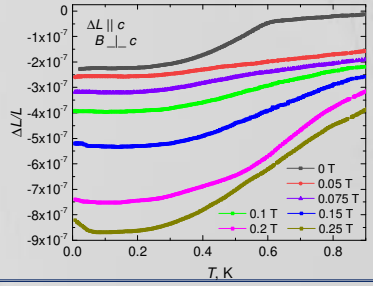
In ***B*** ***||*** ***c*** the magnetisation curve is typical of strongly uniaxial ferromagnets, which proves the magnetic structure to have a large ferromagnetic component along ***c.***

In ***B_|_c*** an inflection point and a small hysteresis appear on the magnetization curve for *B* ~ 0.2 T. This suggests that the magnetic order in the direction perpendicular to the *c* axis has an antiferromagnetic component.

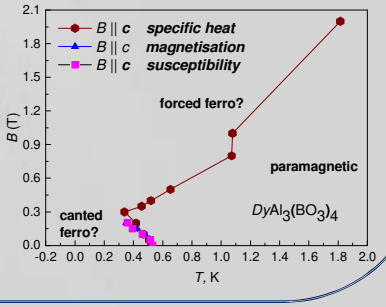
Standard Dilatometer model from Kuechler Innovative Measurement Technology

- ^{3}He-^{4}He dilution refrigerator from Oxford Instruments (base temperature 7 mK)
- ANR200 piezoelectric rotator from Attocube Systems AG
- accuracy of 1/10th of a degree





Determined *B-T* phase diagram.



RESULTS for $DyAl_3(BO_3)_4$

The phase transition to the magnetically ordered phase, at 0.53 K, was discovered and the *T-B* phase diagram was constructed.

It was found that:

- **The magnetic field shifts the transition towards lower temperatures, when smaller than 0.25 T.**
- **The magnetic structure appearing is noncollinear. It has a large ferromagnetic component along the *c* axis and an anitferromagnetic one in the plane perpendicular to this axis.**
- **The phase transition to the magnetically ordered state appears at very low temperature and behaves atypically for ferromagnetic materials under influence of small magnetic field.**

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