Dimensional reduction and extraordinary phase-transition dynamics in the frustrated magnet $DyRu_2Si_2$

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Frustrated magnets are quite attractive subjects for decades because they exhibit rich variety of non-trivial phenomena induced by emergent degeneracies due to the competition of local interactions. Among them, we are interested in the intermetallic rare-earth compound $DyRu_2Si_2$ which is a frustrated Ising antiferromagnet due to the oscillating long-range RKKY interactions. $DyRu_2Si_2$ exhibits the complicated magnetic field ($H \parallel c - axis$) and temperature (T) phase diagram where multiple magnetic ordered phases (denoted as I, II, III, and IV) appear.

The phase I appearing at zero field ($T_{\text{para-I}} =$ 29.5 K) is a partially-ordered phases where the disordered 2-dimensional planes (D_I-plane) are emergent. Interestingly, the phase transition between the phase I and II at zero field is the spin-ordering on this 2-dimensional D_I-plane and the extraordinary slow critical dynamics, the time scale of the order of 100 msec, was observed by the ac-susceptibility measurements [1]. Detailed analysis suggests that the large belt-like-shaped ferromagnetic spin textures on the D_I-planes emerge precedently to the phase transition and they spontaneously arrange into the striped structure of the phase II at the phase transition temperature ($T_{\text{I-II}} = 3.6$ K). This anomalous critical development of spin correlations should be attributed to the low dimensionality and the strong frustration effect in the 2-dimensional D_I-planes.

In order to verify the anomalous development of spin correlations of $DyRu_2Si_2$ attributed to the I-II phase transition, we performed the elastic neutron scattering experiment using the 4G triple-axis-spectrometer at the JRR-3 reactor. The experiment was performed on the (hhl) scattering plane by mounting the single crystalline sample with its $[1\bar{1}0]$-axis oriented vertically.

Figure 1 shows the neutron scattering intensity maps at $T =$ (a) 45 K (para.), (b) 10 K (phase I), and (c) 4 K ($\approx T_{\text{I-II}}$, phase I). The isotropic paramagnetic scattering observed at $T = 45$ K was concentrated on the $[hh0]$ -line when entering into the phase I. This indicates that the spin correlations in the phase I are anisotropic and extremely long along the c-axis, even on the disordered D_I-planes. No significant difference was observed between the magnetic scattering intensity maps at 4 and 10 K within the phase I, and thus, the details of the development of the spin correlations on the D_I-plane attributed to the I-II phase transition is still unknown. It should be because only the limited region in the $(hk0)$-plane, where the spin correlation changes associated with the I-II phase transition are expected, can be observed in the present (hhl) scattering plane. The next experiment with the $(hk0)$ scattering plane should be required.

[1] S. Yoshimoto et al., J. Phys. Soc. Jpn. 92, 094705 (2023)

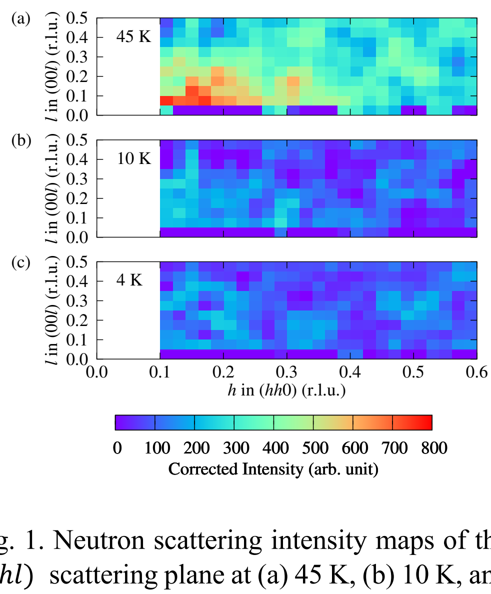

Fig. 1. Neutron scattering intensity maps of the (hhl) scattering plane at (a) 45 K, (b) 10 K, and (c) 4 K. The absorption and orientation factors were corrected. The background, the intensity map at 0.7 K, were subtracted.