Investigation of the magnetic ground state of frustrated spin system 
\( \text{Rb}_2\text{Cu}_2\text{Mo}_3\text{O}_{12} \)

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\( \text{Rb}_2\text{Cu}_2\text{Mo}_3\text{O}_{12} \) is a quantum spin system having a spin-1/2 one-dimensional (1D) zig-zag chain, where spin frustration is expected to result from competition between the first and second neighbor exchange interactions, \( J_1 \) and \( J_2 \). Based on the ratio \( J_1/J_2 \), it has been suggested that the magnetic ground state of this system is novel incommensurate spin-singlet. However, evidence for the spin-singlet ground state has not been bared experimentally. Magnetic susceptibility drops at low temperature but exhibits a nonzero value, and a powder inelastic neutron scattering measurement did not reveal an energy gap, whereas dispersive spin excitations arising from an incommensurate propagation vector were observed. In order to clarify the magnetic ground state of \( \text{Rb}_2\text{Cu}_2\text{Mo}_3\text{O}_{12} \), we performed a muon spin relaxation (\( \mu \)SR) experiment on this material at the RIKEN-RAL Muon Facility.

![Fig. 1. ZF-\( \mu \)SR time spectra observed at various temperatures.](image1)

Figure 1 shows the time spectra observed at various temperatures under zero-field (ZF). The relaxation is gradually enhanced below 10 K, while it shows little change below \( \sim 1.5 \) K. The enhancement of the relaxation is moderate, and a Gaussian-like relaxation is sustained even at the lowest temperature. This behavior indicates the existence of a nonmagnetic ground state without any magnetic order.

![Fig. 2. Temperature dependence of (a) the field distribution width \( \Delta \) and (b) the relaxation rate \( \lambda \).](image2)

The ZF-\( \mu \)SR time spectra are fitted with a relaxation function \( A(t) = AG_{\text{KT}}(\Delta, t)e^{-\lambda t} \), where \( G_{\text{KT}}(\Delta, t) \) is a Gaussian Kubo-Toyabe function that describes a random and static field, \( \Delta \) the distribution width of the random field, and \( \lambda \) the relaxation rate of the muon spin. The temperature dependences of \( \Delta \) and \( \lambda \) are shown in Figs. 2(a) and 2(b), respectively. They show similar trends. They are almost independent of temperature above \( \sim 10 \) K, where the system is paramagnetic. As temperature decreases, both parameters increase simultaneously and saturate at \( \sim 1 \) K. We note that the spectra cannot be fitted with a constant \( \Delta \) value in the whole measured temperature range. Such a temperature dependence of the relaxation rate has been reported in a several spin-singlet systems, and in most cases, the relaxation rate starts to increase concomitantly with the formation of spin-singlet pairs. In the present system, the magnetic susceptibility shows a broad maximum at \( \sim 14 \) K, and then decreases with decreasing temperature. Therefore, the ZF-\( \mu \)SR result indicates the appearance of the spin-singlet state in \( \text{Rb}_2\text{Cu}_2\text{Mo}_3\text{O}_{12} \).

References