Study on the magnetic dynamics of the Shastry-Sutherland lattice antiferromagnet $Pr_2Ga_2BeO_7$

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Materials that exhibit the Shastry-Sutherland lattice (SSL) are of interest due to their potential to host quantum spin liquid (QSL) states. The $Pr_2Ga_2BeO_7$, comprising the frustrated SSL of Pr^{3+} moments, attracts attention as possible QSL candidates. We performed heat capacity measurements at different magnetic fields, indicating that there is no long-range magnetic order down to 0.3 K at 0 T. The fit to the 0T data below 2 K yields α = 2.075. Such a quasi-quadratic behavior would be consistent with a Dirac QSL state in which a $C_m \sim T^2$ behavior is expected by the Dirac nodes. Moreover, the plateau-like behavior in relaxation rate λ_{ZF} vs T obtained by the MuSR measurement has also been observed in several other QSL compounds. The zero-field thermal conductivity (at T < 0.3 K) of $Pr_2Ga_2BeO_7$ can be fitted by $\kappa/T = \kappa_0/T + bT$, where these two terms represent the contributions from itinerant gapless fermionic excitations and acoustic phonons, respectively. The linear fitting of κ/T to T → 0 for H // a and H // c gives the residual values of $\kappa_0/T \sim 0.0105$ W/K^{2}m and 0.0095 W/K^{2}m, respectively. Notably, these values are large enough to be accurately detected by the high-level measurement. The non-zero residual linear term immediately implies that the mobile fermionic excitations from the ground state are gapless, and this is consistent with the results of the specific heat measurements. We are motivated by these interesting properties to conduct more detailed research on this system. To obtain the dynamic spectra of this system, $Pr_2Ga_2BeO_7$ single crystal has been measured at HODACA, JRR-3 recently, which will help us to reveal the complex interaction in $Pr_2Ga_2BeO_7$ and provide vital links between macroscopic properties and microscopic mechanism.

Two pieces of samples were attached on an aluminum sheet and co-aligned in the (0KL) scattering plane. The measurements were carried out at 0.7 K with a fixed final neutron energy, E_f = 3.636 meV. As shown in Figure 1a, the elastic neutron scattering data in the (0KL) plane measured at 0.7 K exhibits no magnetic Bragg peaks and again confirms the lack of long-range magnetic order in $Pr_2Ga_2BeO_7$. The INS spectrum measured at 0.7 K is presented in Fig. 1b and (c) as the spectral intensity along the high-symmetry momentum directions R_1-Z_1-R_2-X_1-R_3 and Z_2-Γ_1-X_1-Γ_2 in energy-momentum (E-Q) space. The main observation is that the spectral intensity is smeared in the whole Brillouin zone but with a gapless feature. Such gapless excitation supports the gapless QSL state in $Pr_2Ga_2BeO_7$. Moreover, the largest intensity is found near the Z_1 point. Based on the data, we can confirm the lack of long-range magnetic order and the gapless feature in $Pr_2Ga_2BeO_7$. Such gapless excitation supports the gapless QSL state in $Pr_2Ga_2BeO_7$, which is consistent with the macroscopic results.

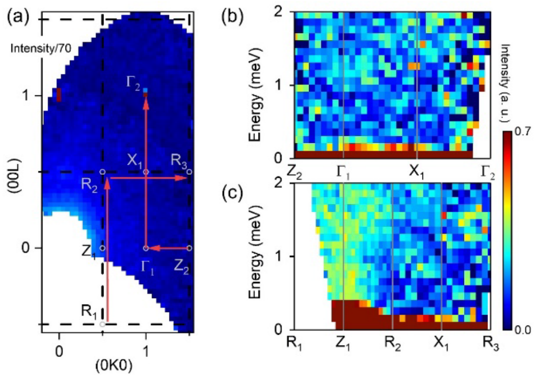

Fig. 1. Single-crystal inelastic neutron scattering results for $Pr_2Ga_2BeO_7$. **a**, Elastic magnetic scattering in the 0KL plane, the black dashed lines represent the Brillouin zone boundaries. The gray hollow circles represent high symmetry points R_1, Z_1, R_2, X_1, R_3, Z_2, Γ_1 and Γ_2 marked in (a). **b** and **c**, Spin-excitation spectra along high symmetry momentum directions R_1-Z_1-R_2-X_1-R_3 and Z_2-Γ_1-X_1-Γ_2, respectively.