

Experimental report

22/01/2024

Proposal: 4-03-1765

Council: 4/2023

Title: Spin excitation and hidden multipolar order in kagome spin ice HoAgGe by inelastic neutron scattering

Research area: Physics

This proposal is a new proposal

Main proposer: Kan ZHAO

Experimental team: Kan ZHAO
Hao DENG

Local contacts: Arno HIESS
Paul STEFFENS

Samples: HoAgGe

Instrument	Requested days	Allocated days	From	To
THALES	7	7	23/08/2023	30/08/2023

Abstract:

Spin ices are exotic phases of matter characterized by frustrated spins obeying local ice rules, that minimize the number of spatially isolated magnetic monopoles. In two dimensions, one can similarly define ice rules for in-plane Ising-like spins arranged on a kagome lattice, leading to unique orders and excitations. HoAgGe is the first natural compound to realize kagome spin ice state (Science 367, 1218;1223 (2020)). One magnetic excitation mode is observed with maximum value of 0.8 meV at ζ point $(-1, 1, 0)$ at 0.1K. Interestingly, another magnetic excitation below 1.6 meV appears at ζ point $(-2, 2, 0)$. It seems really unusual, as we would expect the spin wave should be with high intensity in small q range. Such behavior would be related with the effective transverse field (h) acting on the in-plane Ising spins, which would exhibit unique quantum effects. We plan to do inelastic scattering with polarized neutron at THALES to collect details of this special excitation, to determine the related quantum effect.

ILL experiment report

1 PRINCIPAL INVESTIGATOR

Name and institution of the Principal Investigator

Dr Kan Zhao

BEIHANG UNIVERSITY (BUAA)

NO. 37 XUEYUAN ROAD, HAIDIAN

100083 BEIJING

CHINA

2 EXPERIMENT DETAILS

Reference Number: 4-03-1765

Title: Spin excitation and hidden multipolar order in kagome spin ice HoAgGe by inelastic neutron scattering

Equipment/Facility Used: THALES station

Dates Scheduled: August 2023

3 EXPERIMENT REPORT

In Fig. 1(a), 5 co-aligned HoAgGe single crystals were adopted for inelastic neutron scattering (INS) at THALES, ILL at 0.1 K during July 2021. Fig. 1(a) clearly shows spin wave excitations along $[-K, K, 0]$: one excitation mode is observed with an excitation gap of 0.4 meV at M point $(-0.5, 0.5, 0)$ and maximum value of 0.8 meV at Γ point $(-1, 1, 0)$. It is interesting that another branch below 1.6 meV appears at Γ point $(-2, 2, 0)$, which is relatively weak at Γ point $(-1, 1, 0)$. It seems really intriguing, as the spin wave should be with high intensity in small q range with magnetic dipole moment. Thus, this behavior might be related with the multipolar order nature of Ising spin under transverse field in the triangular quantum magnet TmMgGaO_4 .

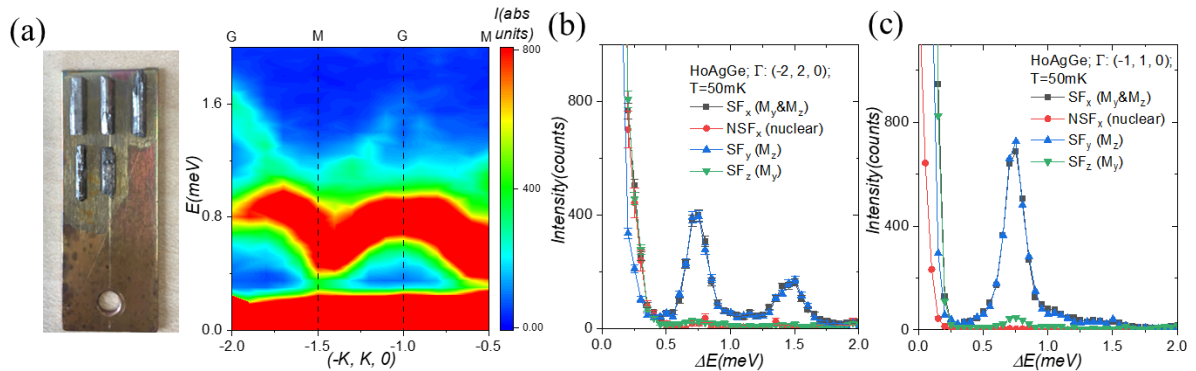


Fig. 1: (a) Spin excitation spectrum of HoAgGe along $[-K, K, 0]$ at 0.1K, with optical image of HoAgGe crystals in left side. (b-c) Energy scans of spin excitation using polarized neutron at Γ point $(-2, 2, 0)$ and Γ point $(-1, 1, 0)$ at 0.05 K, with all three spin-flip (SF) channels and non-spin-flip x channel NSF $_x$.

To track the origin of such novel spin excitations, we did the INS of aligned HoAgGe crystals at 0.05 K on THALES with polarized neutron. And we used the conventional notations to define the polarization directions, x , y and z , in reciprocal space. In details, x is defined to be

parallel to the momentum transfer \mathbf{Q} , and y is perpendicular to x but remains in the scattering plane while z is perpendicular to both x and y , thus perpendicular to the scattering plane. During the measurements, we polarized the incident neutrons along one of the basic directions, x , y or z , and selectively measured the scattered neutrons parallel or anti-parallel to the incident neutrons, which are marked as non-spin-flip (NSF) and spin-flip (SF) channels, respectively.

The INS data at THALES with polarized neutron at 0.05 K during August 2023 in Fig. 1(b-c) has clearly demonstrated that the spin excitations are due to the Mz channel, as the intensity of SF_x ($Mz \& My$) almost equal to that of SF_y (Mz) both at Γ point $(-2, 2, 0)$ and $(-1, 1, 0)$. The result is similar with the TmMgGaO_4 case, where the spin excitations are essentially longitudinally polarized in the Mz channel. The experimental data would help us to construct the theoretical model based on kagome lattice of HoAgGe .