TRIUMF
Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Frustration and magnetism in 1D *zigzag* chain EuL_2O_4

Oren Ofer, Jun Sugiyama, Jess Brewer, Eduardo Ansaldo, Martin Månsson, Kim Chow, Kazuya Kamazawa, Yoshihiro Doi, and Yukio Hintsu

Introduction

One dimensional systems with near-neighbor and next-near-neighbor competing interactions offer an intriguing example of relatively simple systems, which ultimately can be correlated with non-perturbed Hamiltonians. However, many systems show complex magnetic phenomena and multiple phases. These system are often frustrated due to governing Antiferromagnetic interactions and geometrical contraints. The main drawback of in the comparison of these compounds lays in the vast diversity of the chemical and magnetic structures. Therefore, there's an on-going search of a single experimental system which exhibits such remarkable phases.

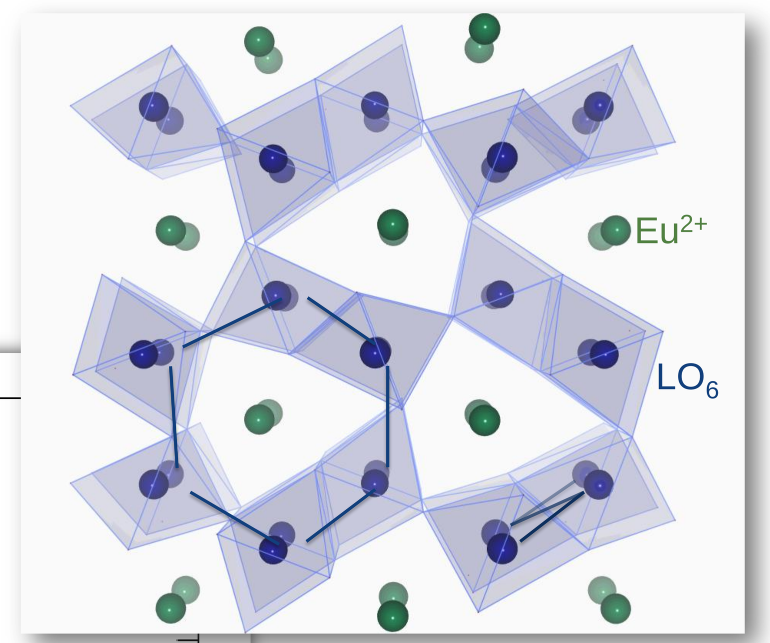
Can we control the magnitude of the magnetic moment of a zigzag chain and use it as a tuning parameter to manipulate the magnetic-frustration/ground state interplay?

The EuL_2O_4 family

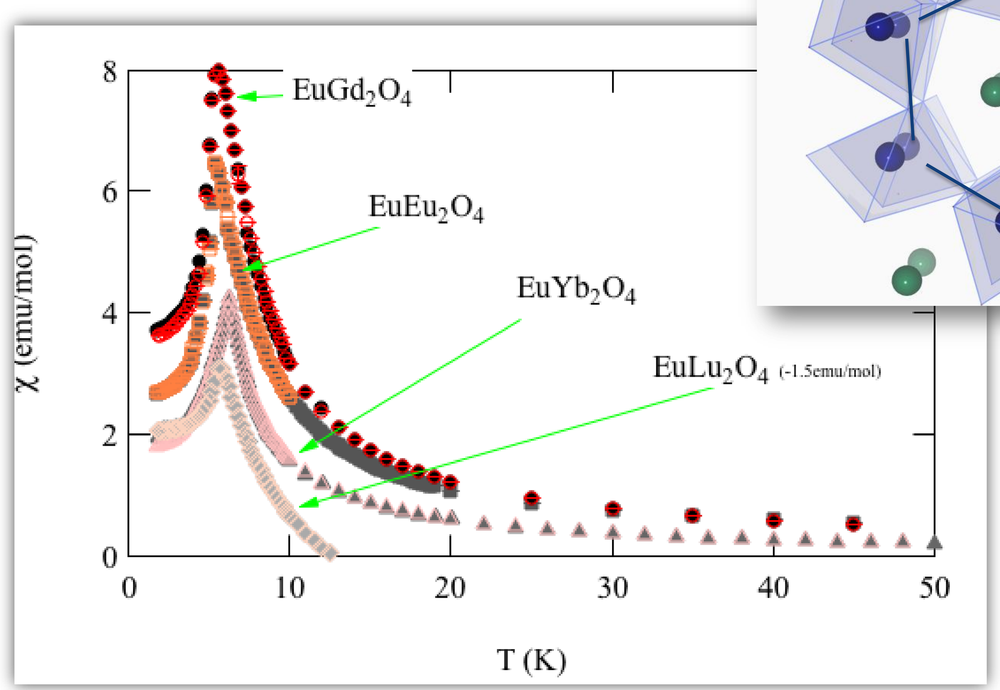
The EuL_2O_4 (L=Lu, Eu, Yb, Gd) crystallizes into a CFO-type structure in which a zigzag chain formed by a network of edge-sharing LO_6 octahedra align along the *b*-axis creating an irregolar hexagonal 1D channel and an honeycomb lattice within the ac-plane.

The similarity between the Lanthanides in this system allow a unique comparison of the magnetic interactions since Yb Gd and Eu have different magnetic moments while Lu has none. Hence we able to probe how the magnetic ground state is affected, from a state where there are no magnetic zigzag chains, hence no frustration along the zigzag ladders (L=Lu), to a state where there's intense frustration with a large magnetic moment (L=Gd).

Bulk susceptibility (χ), shown below, indicate the similarity between the members of the family, all undergo a transition to an ordered AF state around 6 K. Hence the 3-D nature of the transition, in this family, is mainly controlled by the Eu^{2+} ion.



The CaFe2O4 type Pnma crystallographic structure of EuL2O4. The ac –plane honeycomb lattice and the b-axis zigzag chain are shown by the solid lines.



The temperature dependence of the susceptibility for the EuL2O4 family. All members show the typical AF transition occurring at 5.5<T<6.3 K

Results and Discussion

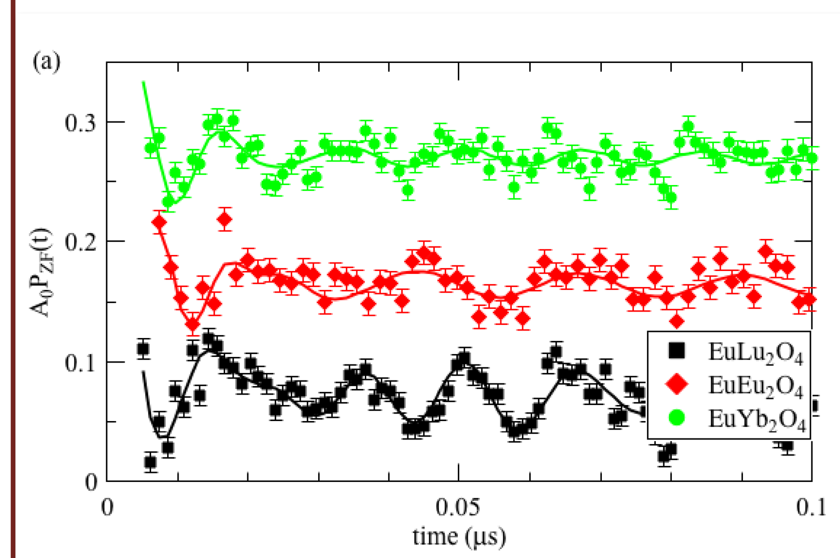
1) Below T_N

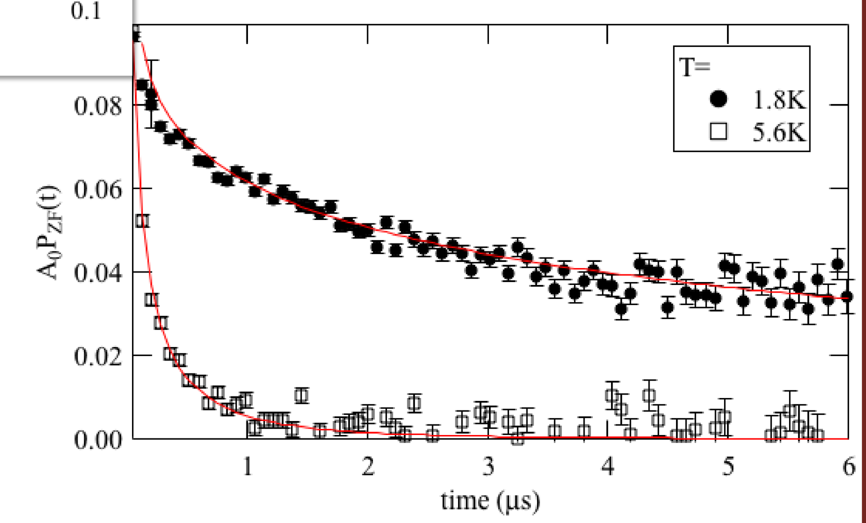
The raw ZF-μSR spectra in L=Lu, Eu and Yb indicate a single frequency. In L=Eu and Yb the fit to a cosine function, $A_{AF}\cos(2\pi f_{AF}t+\varphi)$, show the initial phase φ, to be non-zero, indicating a large internal field distribution at the muon site(s). Suggesting a formation of incommensurate AF order.

Fitting $f(T)$ to a BCS-order parameter type, $f = f_0 \tanh(1.74\times(1-T/T_N)^{\beta})$

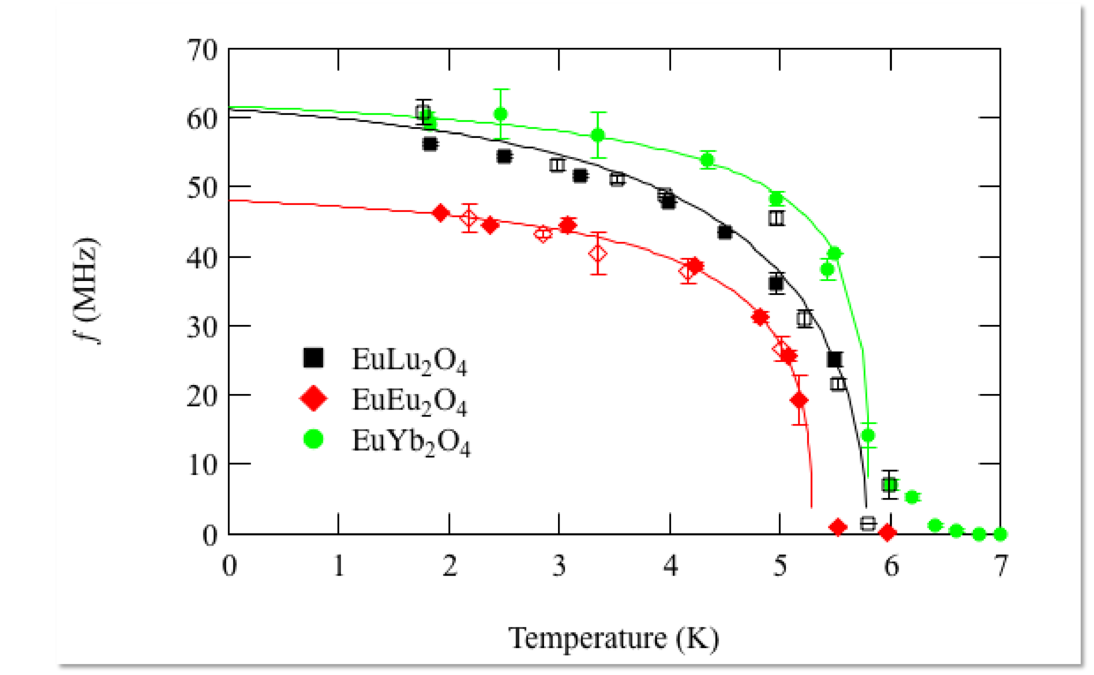
indicate that the critical exponent, β, which is related to the Hamiltonian describing the magnetic system decreases systematically with increasing moment.

The L=Gd do not show a formation of a static magnetic order but slow-relaxation. The data is well fitted globally by $A_0P_{ZF}(t)=A_0\exp(-(\lambda_{ZF}t)^{\beta})$ with $\beta=0.42(8)$





(a) The oscillating ZF-spectra for L=Lu, Eu and Yb. (top) (b) The damped relaxation observed for L=Gd. (right)



The temperature dependence of the muon precession frequency, f, of L=Lu, Eu and Yb. Filled symbols measured in ZF, hollow in wTF. Lines indicate the T dependence of the BCS gap energy.

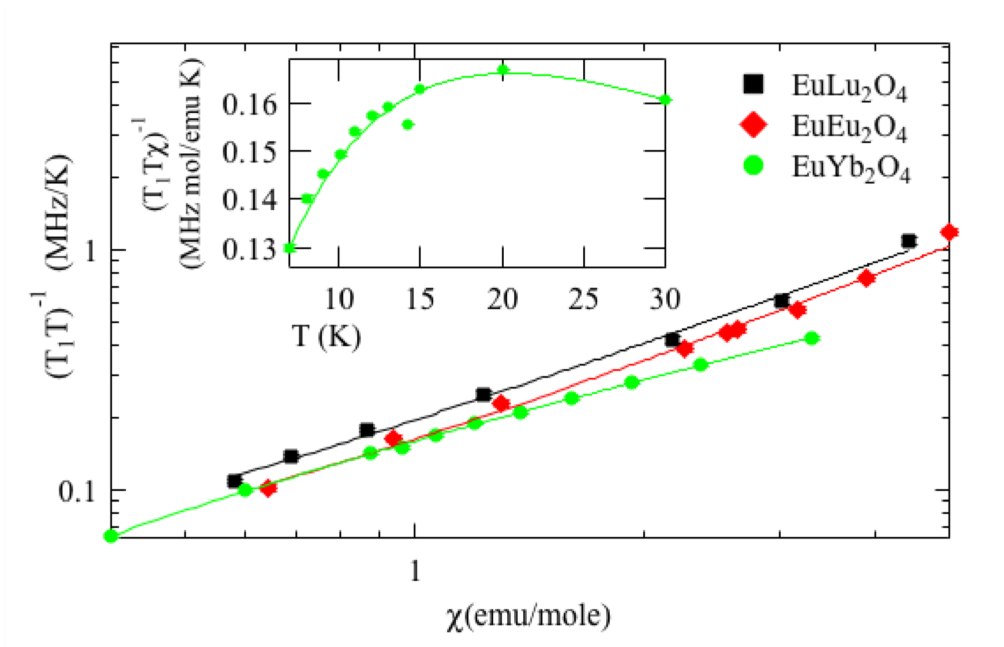
2) Above T_N

Due to the 3-D nature of the transition, the 1-D character is probed above Tn.

The ZF-spectra is fitted, for each compound, globally to $A_0P_{ZF}(t)=A_0\exp(-(\lambda_{ZF}t)^{\beta})$

Spin fluctuations theories suggests $(T_1T)^{-1}\propto\chi^{n}$ hence, the relaxation, extracted from the fits, is fitted to χ^{n}. Where the negative curvature of L=Yb, suggests that the relaxation is driven by random field fluctuations, hence

$(T_1T\chi)^{-1}=A\tau/(1+\omega^2\tau^2);\quad \tau\propto T^{-n}$



Summary

- The theoretical XXZ Hamiltonian predicts multiple magnetic phases controlled by J1/J2 and anisotropy. Here we were able to manipulate the ground state by the chemical substitution of the magnetic ion.
- Bulk measurements indicate the similarity of the family members showing an Antiferromagnetic transition below 6.5K.
- μSR data revealed the difference between compounds, indicating the formation of a static AF (L=Lu), a mixed AF/IC-SDW (L=Eu), an IC-SDW (L=Yb) ordered phase, and a dynamic disordered phase (L=Gd).
- Thus the difference in the magnetic moment reveal that static AF order becomes dynamic as the magnetic moment along the zigzag chain increases.

References

Oren Ofer *et al.,* Phys. Rev. B **82**, 094410 (2010).
Jun Sugiyama et. al., Phys. Rev. B **79**, 104432 (2008).
Keiichi Hirose *et. al.,* J. Solid State Chem. **182**, 1624 (2009).
Oren Ofer *et al.* , submitted to PRB (2011).

Acknowledgments

We are grateful to TRIUMF staff for assistance with the μSR experiments. JHB and KHC are supported by NSERC of Canada and (through TRIUMF) by NRC of Canada. This work is also supported by a Grant-in-Aid for Scientific Research (B), 19340107, MEXT, Japan.