Prospectus

Catie Robinson

June 10, 2022

1 Introduction

A quantum spin liquid is a quantum ground state of magnetic moments where there is no long range magnetic order but rather a superposition of many singlet states creating a disordered ground state. This disordered ground state then leads to interesting unconventional excited states. [2, 7]

Quantum spin liquids have been a recent area of interest because of how this superposition of states can be used in quantum information. These quantum Spin liquids have been well explored in insulating materials, but have yet to be fully explored in metals because the conductivity of metals often gives rise to a preferred magnetic order due to longer ranged magnetic interactions, as opposed to the more interesting quantum spin liquid state. [2, 7]

Previous studies have observed these unconventional magnetic states in the material Yb_2Pt_2Pb, so in attempt to find these in another material we plan to grow samples of Ce_2Ge_2Mg. [6, 1] We've chosen Ce_2Ge_2Mg as a good candidate to again find these unconventional excited states, because it not only is of the same general form as Yb_2Pt_2Pb, rare earth metal, transition metal, and main group element, but it also shares the same crystal structure, similar basic physical properties, and similar discontinuities in the derivatives of magnetic susceptibility and magnetization. [4]

So, the goal of our project will be to make these crystals of Ce_2Ge_2Mg, to allow for better study and eventual use of quantum spin liquids in metals.

2 Procedure

To grow these crystals of Ce_2Ge_2Mg we plan to use the flux method where the elements in their necessary proportions are dissolved together in a solvent at high temperatures and then given time to crystallize before draining off the excess solvent [3, 5]. Unfortunately, a problem arises when performing this process to form Ce_2Ge_2Mg, because the elements must be dissolved in magnesium, but magnesium's high vapor pressure makes it difficult to keep as a liquid to act as the solvent. In order to overcome this, we will seal the elements in a strong niobium tube to contain the pressure of the heated magnesium thus allowing it to stay liquid and the desired crystals to form.

After creating the samples we will perform various measurements such as scanning electron microscopy, x-ray diffraction, and basic physical properties like specific heat, magnetization, and resistivity as functions of temperature and magnetic field.

This process of creating Ce_2Ge_2Mg has been successfully done before using much more expensive tantalum tubing, so we will also be looking to see if the use of niobium tubing causes any impurities or other effects different from previous samples made from tantalum tubing.[4] Hopefully, this process will allows us to make high quality crystals much more affordably that can then be used to further explore quantum spin liquids. If we are successful in the creation of these samples, we can hopefully create enough to perform a neutron scattering experiment to see if this material does indeed have the unconventional magnetic excited states.

References

[1] Wu et al. "Orbital-Exchange and Fractional Quantum Number Excitations in an f-Electron Metal, Yb2Pt2Pb". In: *Science* 352 (2016).

[2] A. Alexandradinata et al. *The Future of the Correlated Electron Problem*. 2020. DOI: 10.48550/ARXIV.2010.00584. URL: https://arxiv.org/abs/2010.00584.

[3] Paul C Canfield. "New materials physics". In: *Reports on Progress in Physics* 83.1 (2019), p. 016501.

[4] W. J. Gannon. *The Antiferromagnetic Phase diagram of the metallic Shastry-Sutherland Lattice compound Ce2Ge2Mg, Pre-print*.

[5] Mercouri G Kanatzidis, Rainer Pöttgen, and Wolfgang Jeitschko. "The metal flux: a preparative tool for the exploration of intermetallic compounds". In: *Angewandte Chemie International Edition* 44.43 (2005), pp. 6996–7023.

[6] M. S. Kim, M. C. Bennett, and M. C. Aronson. "Yb_2Pt_2Pb: Magnetic frustration in the Shastry-Sutherland lattice". In: *Phys. Rev. B* 77 (14 Apr. 2008), p. 144425. DOI: 10.1103/PhysRevB.77.144425. URL: https://link.aps.org/doi/10.1103/PhysRevB.77.144425.

[7] Lucile Savary and Leon Balents. "Quantum spin liquids: a review". In: *Reports on Progress in Physics* 80 (2017), p. 016502.

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