SEARCH FOR NEW YTTERBIUM-BASED HEAVY FERMION COMPOUNDS

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Quantum phase transitions are a rich area of potential research however we still do not have enough compounds that exhibit these transitions to discover their full host of potential applications. We have been working on synthesizing Ytterbium-based heavy fermions that we believe will display these transitions and so provide vital data points for ongoing research. We choose to examine Yb due to the similar magnetic properties that it shares with Cerium. Many compounds containing Ce have been found to be heavy fermions, one of the necessary conditions for quantum phase transitions, however Yb remains relatively unprobed by comparison. Using phase diagrams we constructed temperature profiles to heat up mixtures of elements in hopes of growing crystals of YbTT'(T=Rh, Pd, Ir and T'=Ge, Sn, Bi). X-ray measurements were then done to determine the composition, and magnetization, resistivity and specific heat data will be used to identify compounds with heavy fermion behavior.

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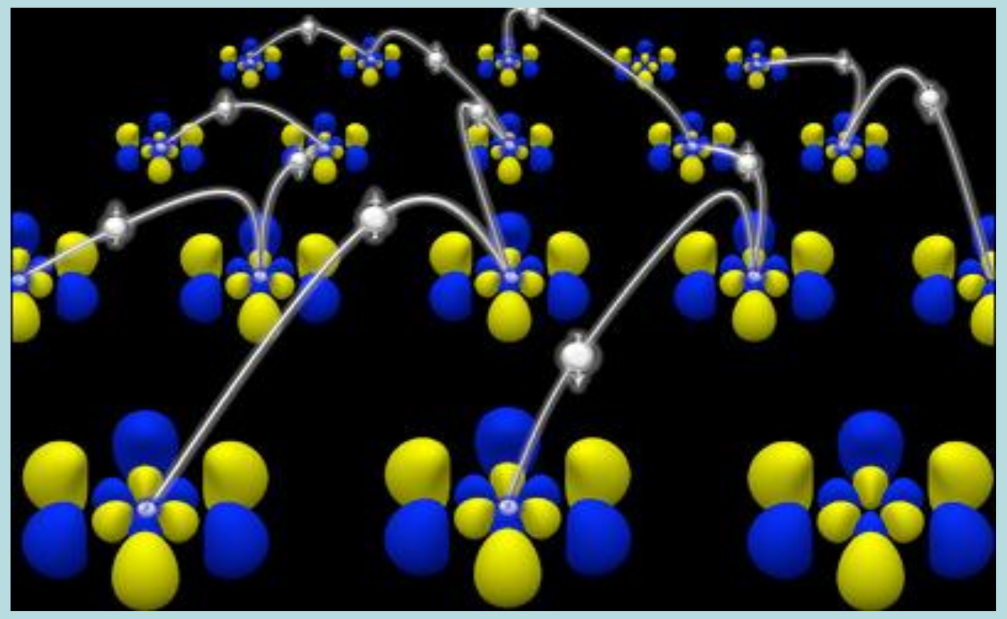
The Significance of Heavy Fermion Compounds

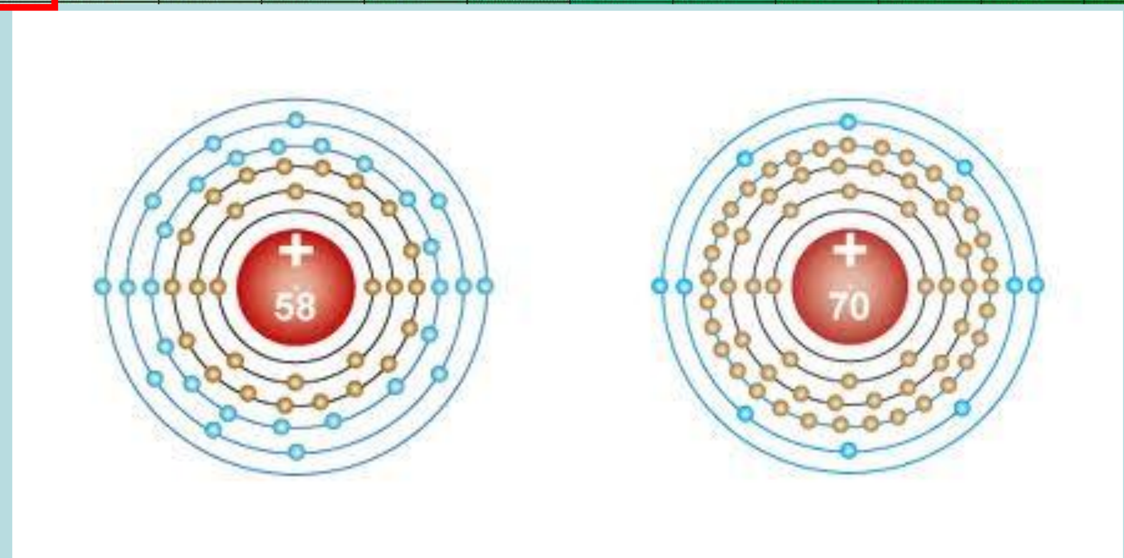
Heavy fermion compounds are unique in that their conduction electrons exhibit a weight up to 1000 times greater than their free electron analogous. This gives some of them the ability to exhibit quantum phase transitions. It is one of the ultimate goals of the Morosan lab to discover more compounds that display quantum phase transitions and therefore I spent my research trying to find more heavy fermions.



Mohammad Hamidian/Davis Lab

The Relevance of Ytterbium

Many compounds containing Cerium have been found to be heavy fermions however extensive work has already been done on this element. Ytterbium shares similar magnetic properties to Cerium due to the fact that it is 1 hole from a full f shell and Cerium is one electron from a full f shell. Yet by comparison no stoichiometric Ytterbium-based heavy fermions have been found. Thus my research was based around trying to find the “missing heavy fermions” that we have not yet discovered in Ytterbium based compounds.



Cerium Electron Configuration *Ytterbium Electron Configuration*

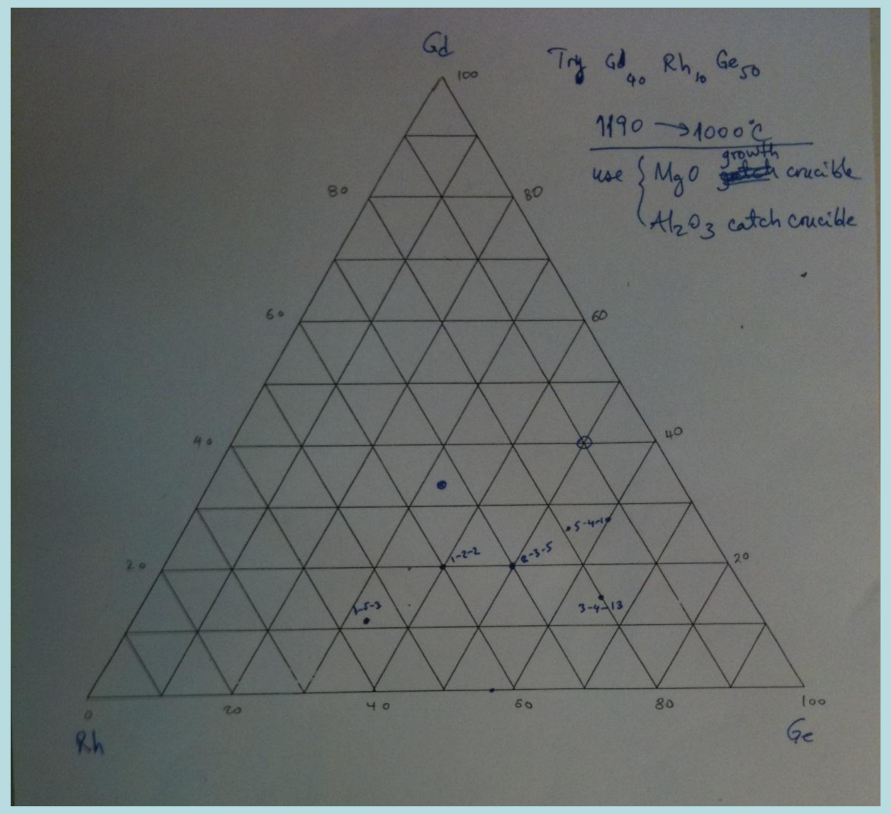
Synthesis of the Compounds Using Liquid Flux Growth

The first step of the synthesis was the construction of ternary phase diagrams to determine the best compound ratio to work with. The elements were then mixed together in appropriate ratios in evacuated sealed quartz tubes. This mixture was then heated until all it’s constituents were liquidized followed by a cooling process which would hopefully separate the crystals from the flux. After the heat cycle was over the crucibles were quickly removed from the furnace and put through a centrifuge to spin off all of the impurities so that we were left with was single crystals.

Vacuum Line *Furnace* *Centrifuge*

The Second Stage of Synthesis

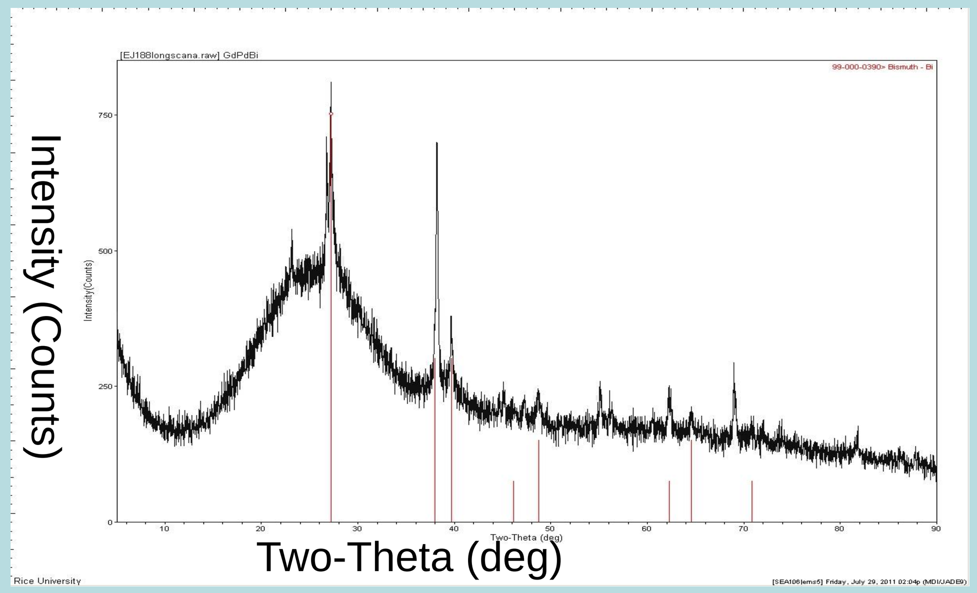
The difficulty in making single crystals is not in the actual synthesis of the crystals themselves but in the design of the appropriate recipe. First attempts at making single crystals usually resulted in some other combination of elements that we had not anticipated. For example, when trying to create GdIrSn the crystals that formed were instead those of GdSn2. In these situations we would go back to ternary phase diagrams and mark the point we now knew to avoid and try to find a better starting ratio.



Ternary Phase Diagram for GdRhGe

Resulting Compounds and the Next Step

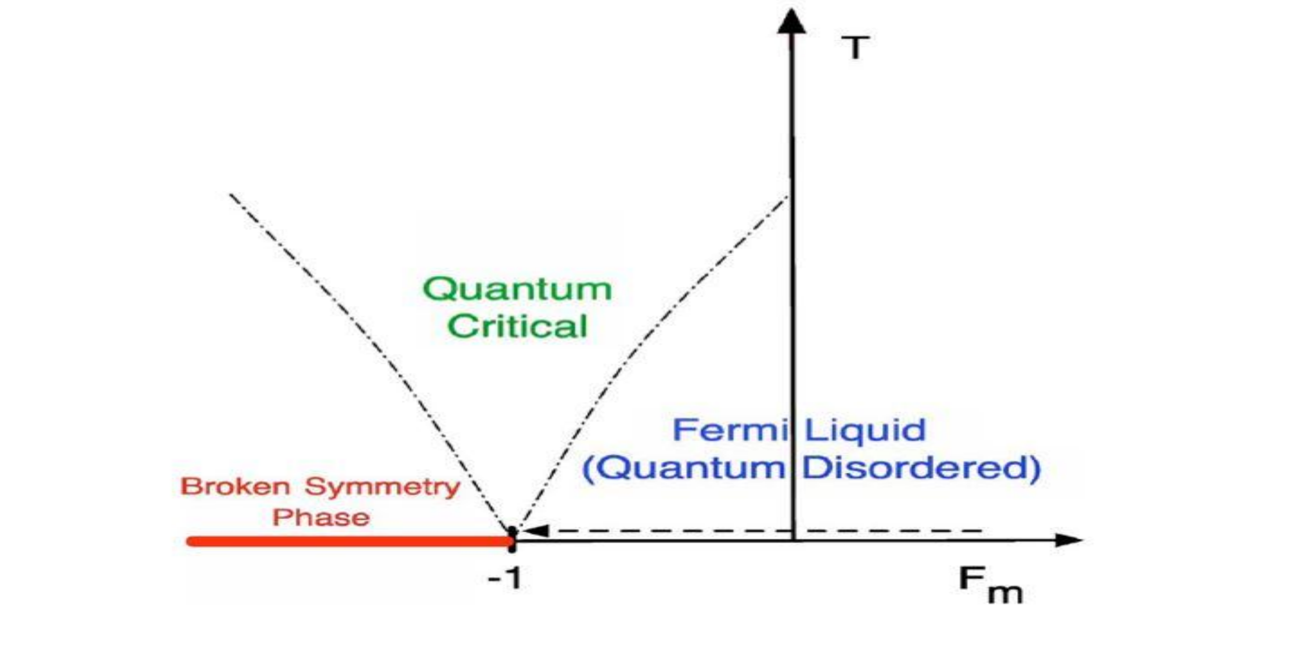
Given the nature of the research finding the desired crystals is still a work in project however I have been able to make significant steps in determining the correct method of production. An example of this is when we tried to produce YbRhGe with the original ratio of 5:30:65. It turned out that we hadn’t had enough Ytterbium and the resulting compound was Ge22Rh17. To correct for this we substituted Ytterbium with the more predictable Gadolinium and increased the ratio of rare earth metal. In this manner we were able to get closer and closer to synthesizing the desired single crystals, this information can they be used in further attempts.



Magnetic Resonance Graph For GdPdBi

Possible Applications

Quantum phase transitions are still an area very much based on theory right now and most research, mine included, about them tends to be more about understanding the fundamental physics rather than applying them to real life products. This is not to say however that no applications will ever result from this research. Once we understand exactly what causes quantum phase transitions it is likely that unexpected possibilities will present themselves where we can apply the knowledge we gained to other areas of the field. Quantum phase transitions however by their very nature of requiring T = 0 K will in all likelihood never have any direct use.



http://physics.bu.edu/~neto/Topic01.htm

A very special thank you to the entire Morosan lab for all the help they provided. In particular I am indebted to Professor Morosan for guiding my research.

This material is based upon work supported by the National Science Foundation’s PIRE Program (OISE-0968405)

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