Re-explaining Heavy-Fermion Magnetism through Crystallography

E. Bervas [1,2], S. H. Moody [1], M. Ciomaga-Hatnean [1,3], E. Pomjakushina [1]

1 PSI Centre for Neutron and Muon Sciences (CNM), Paul Scherrer Institut (PSI), Villigen, Switzerland. 2 Swiss Nanoscience Institute, Klingelbergstrasse 82, 4056 Basel. 3 Materials Discovery Laboratory, Department of Materials, ETH Zürich, Switzerland.

eva.bervas-soloview@psi.ch

$Ce(Cu_{1-x}Ni_x)_2Ge_2$ has been studied for decades as the archetypal heavy-fermion system. The competition of the Kondo and Ruderman-Kittel-Kasuya-Yosida (RKKY) interactions in these compounds leads to the formation of a number of doping-dependent magnetic states [1]. Chemical pressure is the driving force behind this competition. However, applying pressure to $CeCu_2Ge_2$ does not replicate the different types of magnetism seen in the doped samples. As such, it has been established in the literature that these different magnetic states are in fact created due to how differently Cu and Ni hybridise with the Ce orbitals [2].

With this in mind, we have made an exciting new discovery. Neutron diffraction performed at PSI on $Ce(Cu_{1-x}Ni_x)_2Ge_2$ (for x=0.25, 0.25, 0.8) has revealed the presence of extra peaks forbidden by the reported space group I4/mmm (e.g 100, 120, …). By combining neutron and X-ray diffraction we successfully attributed these peaks to a superstructure of Cu/Ni. It seems these 3d metals do not simply randomly arrange on the same site as was previously assumed. For example, for $CeCuNiGe_2$, this leads to a doubling of the unit cell in the c-direction and symmetry lowering to Pmm2 (see fig. 1).

This superstructure is of crucial importance to the physical properties of these compounds. Indeed, it produces four distinct Ce sites with different Cu/Ni nearest-neighbours and oxidation states. It had always been assumed in the literature that these dopants simply form a solid solution leading to an average and identical contribution to each Ce ion. This superstructure shatters this idea and opens up the possibility that not all Ce sites are Kondo compensated or only some of them are taking part in the AFM ordering.

In this talk, I will present how neutron diffraction experiments were crucial in discovering this previously unreported superstructure in $Ce(Cu_{1-x}Ni_x)_2Ge_2$. I will also detail how just how crucial this crystallographic discovery is, both in terms of the Kondo compensation of the Ce moments, and more broadly the heavy-fermion magnetism in this system.

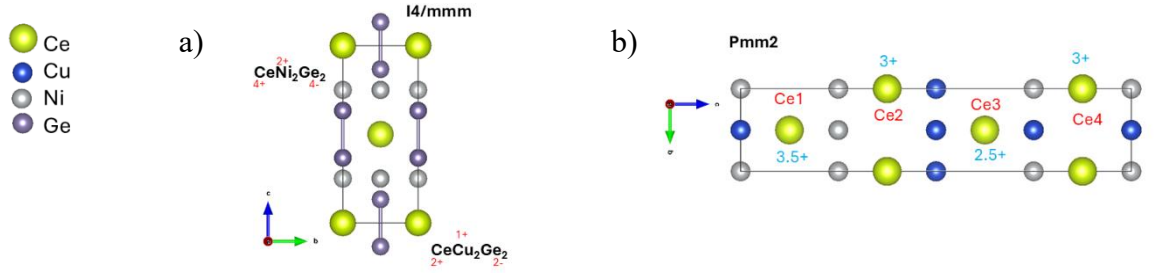


Figure 1. *a) Parent structure of $CeNi_2Ge_2$ with I4/mmm symmetry. The oxidation states for both the Cu and Ni parent compounds have also been included. b) Crystal structure of $CeCuNiGe_2$ (Ge ions omitted for figure clarity). The superstructure of Cu/Ni produces distinct Ce sites which can impact the physical properties of the compound.*

[1] A. Loidl et al., Ann. Physik 1 (1992). 504, 78-91.
[2] F. Steiglich et al., Phys. B (1996). 223 & 224, 1-8.

This work is supported by the Swiss Nanoscience Institute.