ESRF	**Experiment title:** Origin of the induced ferromagnetism in the superconducting ruthenocuprate $RuSr_2RECu_2O_8$	**Experiment number**: HE-1361
Beamline: ID15a	**Date of experiment**: from: 16/07/03 to: 22/07/03	**Date of report**: 13/01/05
Shifts: 18	**Local contact(s)**: Nozumi Hiraoka	*Received at ESRF:*

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Report:

The rare-earth ruthenocuprates $RuSr_2RECu_2O_8$ (RE=Gd,Y,Eu) are a class of material which exhibit coexistence of superconductivity and magnetic order. This experiment was the first investigation of the magnitude and origin of the bulk spin moment of the Gd member of the series using magnetic Compton scattering (MCS). From neutron scattering measurements $RuSr_2GdCu_2O_8$ is thought to order as a G-type antiferromagnet in zero field, the ferromagnetically ordered Ru-O planes coupled antiferromagnetically between the planes, with T_N=130±1K. This order remains with the onset of superconductivity, confined to the Cu-O planes, at T_C~35K although this is highly dependent on the annealing temperature in the sample synthesis. The Gd sublattice orders separately to the Ru-O layers at 3.0±0.3K, it is thought on the basis of magnetisation measurements that the Gd orders ferromagnetically (with the Gd site occupying the ½,½,½ position of the BCT structure) with the moments confined to the C axis and antiferromagnetically coupled with respect to the Ru-O planes. We investigated the anisotropy of the magnetisation density in the three distinct regions of; magnetic order, 35K<T<133K, the coexistence region, 2.5K<T<35K, and order in the Gd sublattice, T<2.5K. Although the sample investigated here is not superconducting the properties determined by magnetometry were unchanged.

MCS samples the spin-dependent electron momentum density through the use of circularly polarised synchrotron radiation. The technique involves high-energy inelastic scattering of a

monochromatic beam of circularly polarised photons E_I=200-250keV. The energy dispersion of the scattered beam is directly related to the electron momentum distribution. In this case, an energy of ~205keV was used, with a scattering angle of ~172 degrees, which gives the optimal resolution and countrate. The 13 element Ge detector was used, giving a total countrate of ~100kcps. In order to extract the spin polarised signal two measurements are made with parallel and antiparallel applied field directions with respect to the scattering vector. The magnetic field was applied using the 1.0T electromagnet installed on ID15a, and an "orange" cryostat was used, with kapton windows to minimise background scattering.

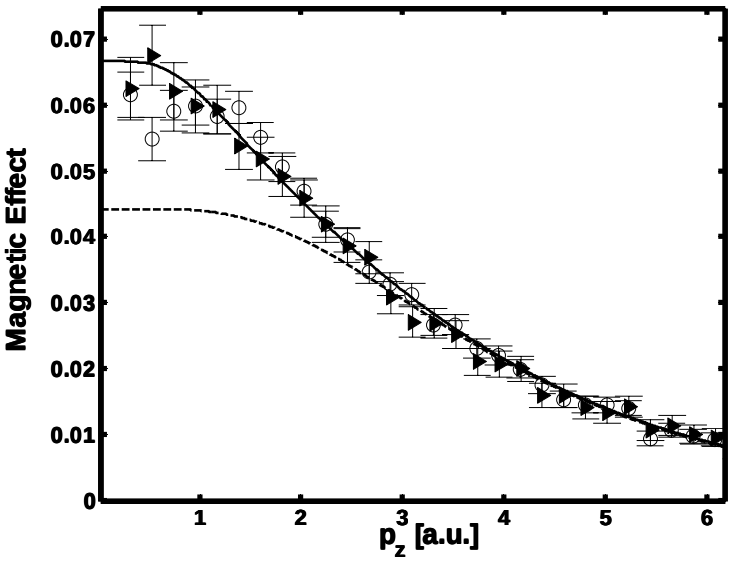

Figure 1. MCP of $RuSr_2GdCu_2O_8$ at 2K (○) and 8K (►) normalised to 1 over the 4f electron momentum region to allow comparison of profile shapes. 2 Hartree-Fock fits are added: a Gd 4f moment (--), and Gd 4f with a Ru 4d contribution (—)

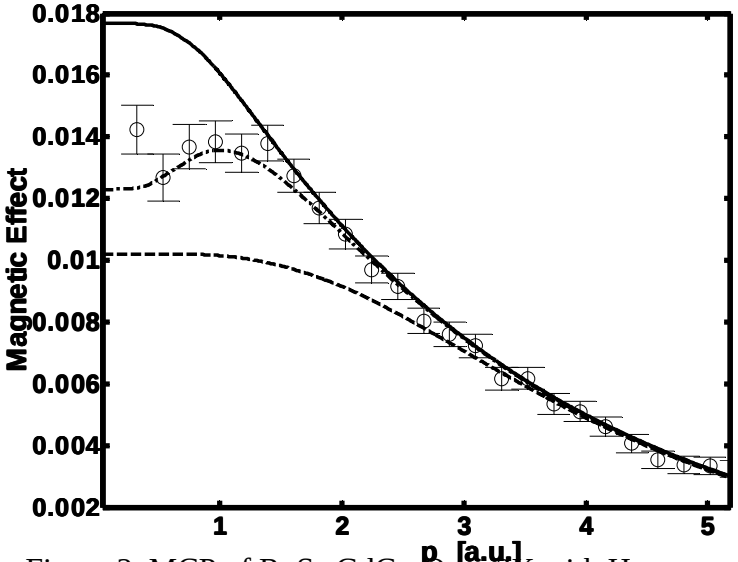

Figure 2. MCP of $RuSr_2GdCu_2O_8$ at 2K with Hartree-Fock model fits: Gd 4f moment (--), Gd 4f and Ru 4d contribution (—), and these Gd4f and Ru 4d moments with an oppositely polarised Gd 5d contribution (•-•).

The magnetic Compton profile (MCP) at 2K shows a dip at low momentum, p_z~0.55 a.u., not present above the Gd sublattice ordering temperature (see figure 1), indicative of a small negatively polarised moment. By comparison with Hartree-Fock free atom electron momentum spin density profiles we can identify the electrons which contribute to the measured spin moment by their width in momentum space. Both MCPs show a large Gd 4f electron spin moment with a significant Ru 4d contribution.

Using this method we conclude that the dip in the momentum region is consistent with a negatively polarised Gd 5d moment (see figure 2). This agrees with observations of antiferromagnetism in Gd in other systems.