Competition between antiferromagnetism and superconductivity in $CeCu_2Si_2$

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The ground state of the heavy-fermion compound $CeCu_2Si_2$ can either be an unusual type of magnetic order, called A-phase, sometimes coexisting with superconductivity, or A/S-type where superconductivity expels the A-phase, or only S(uperconducting). We report on neutron diffraction and inelastic neutron scattering experiments on magnetically ordered $CeCu_2Si_2$ single crystals exhibiting A- and A/S-phase anomalies in specific heat and thermal expansion. Below $T_N \approx 0.8\,K$ antiferromagnetic superstructure peaks have been detected. From an analysis of the magnetic intensities the ordered moment is estimated to $\sim 0.1\,\mu_B$. The propagation vector of the magnetic order, $\tau = (0.215\ 0.215\ 0.530)$ at $T = 50\,mK$, appears to be determined by the topology of the Fermi surface of heavy quasiparticles as indicated by renormalized band-structure calculations. The observation of incommensurate antiferromagnetic order as the nature of the A-phase in $CeCu_2Si_2$ suggests that a spin-density-wave instability is the origin of the quantum critical point in $CeCu_2Si_2$. Further measurements on an A/S-type single crystal prove the long-range nature of the magnetic order. Elastic high-resolution neutron scattering on both, A- and A/S-type crystals, confirms the long-range nature of the antiferromagnetic order in the A/S-crystal but reveal a considerable line broadening for the A-type crystal pointing to a finite domain size or correlation length. However, in energy scans no increased width of the magnetic peaks has been detected indicating an infinite lifetime within the resolution. Extensive measurements, performed on the A/S-crystal also in magnetic fields, reveal that in this crystal antiferromagnetism and superconductivity seem to exclude each other on a microscopic scale.