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Magnetically driven superconductivity in $CeCu_2Si_2$

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The origin of unconventional superconductivity, including high-temperature and heavy-fermion superconductivity, is still discussed controversially. Spin excitations instead of phonons are thought to be responsible for the formation of Cooper pairs. Unconventional superconductivity is quite often observed in the vicinity of a magnetic quantum critical point (QCP), i.e., a continuous magnetic phase transitions occurring at $T = 0$. Such a QCP can be approached when tuning a continuous finite temperature phase transition to $T = 0$ by means of a non-thermal control parameter like doping, pressure or magnetic field. As a result of the quantum-critical spin fluctuations unusual low-temperature properties are observed. The heavy-fermion compound $CeCu_2Si_2$ displays unconventional superconductivity and is already at ambient pressure located in the vicinity of a QCP where long-range antiferromagnetism vanishes. Using elastic and inelastic neutron scattering we studied in detail the antiferromagnetic order and the spin excitations spectrum around the QCP. Antiferromagetism and superconductivity exclude each other on a microscopic scale. While for magnetically ordered samples critical slowing down of the spin fluctuations above T_{N} is observed, shows the normal state response of superconducting $CeCu_2Si_2$ an almost critical slowing down for $T \to 0$. Its temperature dependence and scaling behavior are in line with the expectations for an itinerant spin-density-wave QCP. This interpretation is substantiated by an analysis of specific heat data and the momentum dependence of the magnetic excitation spectrum. The magnetic response in the superconducting state is characterized by a transfer of spectral weight to energies above a spin excitation gap. Compared to the condensation energy there is a larger saving of magnetic exchange energy as the system condenses into a superconducting state. Our results strongly imply that the coupling of Cooper pairs in $CeCu_2Si_2$ is mediated by overdamped spin fluctuations.