Magnetic cooling through quantum criticality

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The proximity of a quantum critical point can significantly affect a material’s thermodynamic properties even at finite temperatures. Here we demonstrate that the accumulation of entropy around a $B$-induced quantum critical point opens up new possibilities for realizing a very efficient low-$T$ magnetic coolant. For the proof of principle, we focus on a simple model substance - a Cu\textsuperscript{2+}-containing coordination polymer $[\text{Cu}((\text{C}_2\text{O}_4)(4\text{-aminopyridine})(\text{H}_2\text{O}))_n$ - a very good realization of a spin-1/2 antiferromagnetic Heisenberg chain with a weak intrachain coupling constant $J/k_B = (3.2 \pm 0.1)$ K, corresponding to a saturation field $B_s = 4.09$ T. To investigate its potential as a coolant, demagnetization experiments have been performed from $B_i > B_s$ under almost adiabatic conditions. While the cooling process is initially linear in $B$ - such as is seen in standard paramagnets - it becomes superlinear upon approaching the QCP at $B_s$. In addition, the quantum critical system excels by its high efficiency $\Delta Q_c/\Delta Q_m$, which exceeds the figures found in state-of-the-art paramagnetic coolants by a factor 2-3. Here $\Delta Q_c$ is the heat the material can absorb after demagnetization to a final field $B_f$, and $\Delta Q_m$ the heat of magnetization released to a precooling stage held at a temperature $T_i$, the initial temperature of the cooling process.