Ubiquitous Spin Freezing in the Superconducting State of UTe_2

S. Sundar[1], N Azari[1], M. Goeks[1], S. Gheidi[1], M. Abedi[1], M. Yakovlev[1], S. R. Dunsiger[1], J. M. Wilkinson[4], S. J. Blundell[4], T. E. Metz[2], I. M. Hayes[2], S. R. Saha[5], S. Lee[3], A. J. Woods[3], R. Movshovich[3], S. M. Thomas[3], P. F. S. Rosa[3], N. P. Butch[2], J. Paglione[2], J. E. Sonier[1].

[1]Simon Fraser University, [2]University of Maryland, [3]Los Alamos National Laboratory, [4]University of Oxford

Introduction

In 2019, superconductivity was discovered in UTe_2 below T_c ~ 1.6 K [1]. UTe_2 is a candidate for a rare topological spin-triplet superconductor, which have potential applications in superconducting spintronics and quantum computing. We have applied μSR to investigate the magnetic interactions in UTe_2 believed to mediate spin-triplet superconductivity.

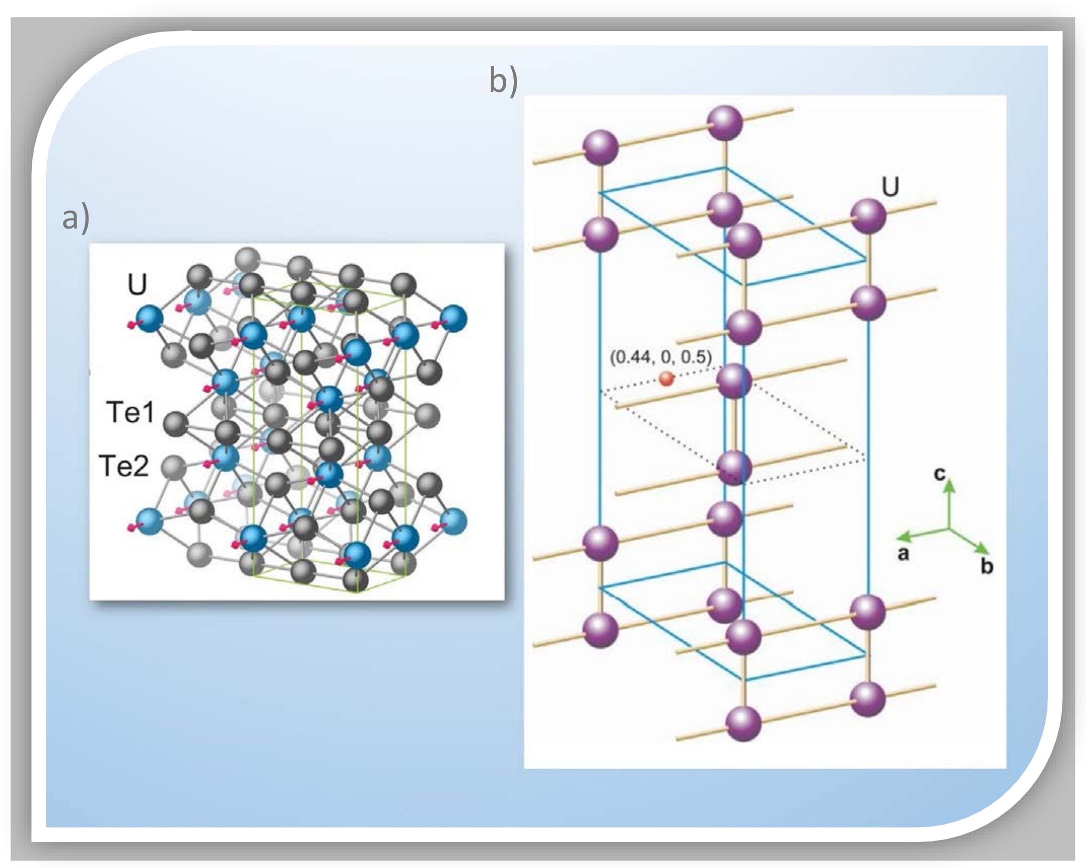

Figure 1: a) Crystal Structure of UTe_2 [1]. b) The predicted muon stopping site.

Specific heat anomaly

Temperature dependence of the specific heat of the UTe_2 samples studied by zero-field (ZF) μSR, plotted as *C*/*T* versus *T* (Fig. 2). The specific heat exhibits a ubiquitous low-*T* upturn and an anomalous extrapolated *T*-linear component. There is also a double transition observed in the specific heat of sample S1 (Fig. 2).

μSR detection of magnetic clusters

Three contributions to the sample component of the ZF signals in Fig. 3:

- Slowly fluctuating or static local internal fields (first term with λ_1, due to magnetic clusters)
- within the μSR time window (second term with λ_2 due to the independent spins that mediate interactions between the clusters)
- too fast that the muon spin completely decouples from the local field (third term, temperature independent non-relaxing)

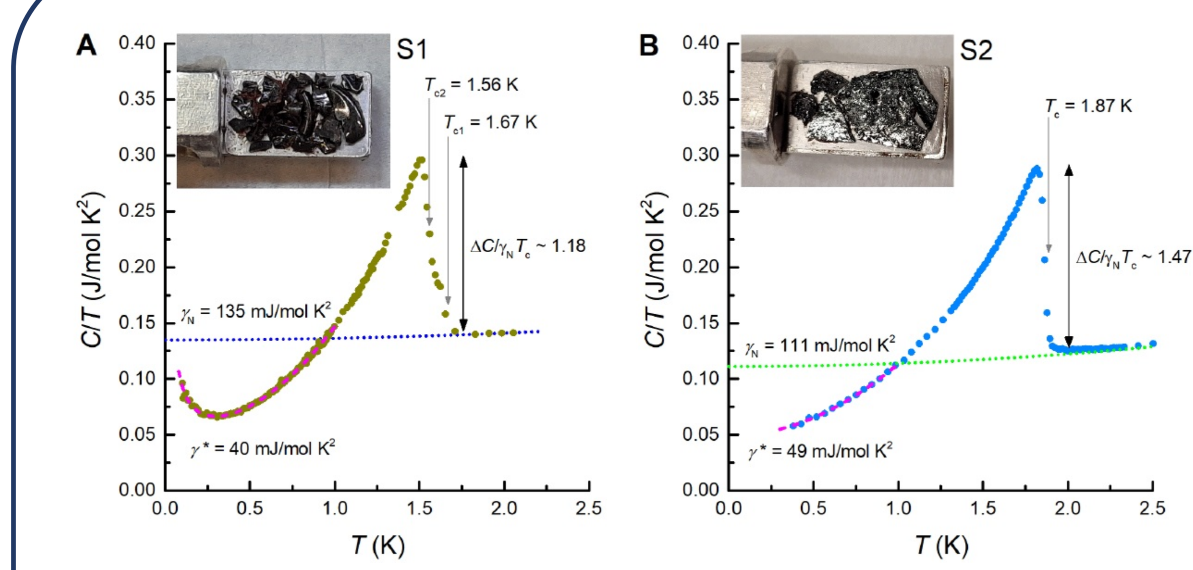

Figure 2: specific heat anomalies, low-*T* upturn and double phase transition in sample S1 only

$$a_0 P_z(t) = a_1 e^{-\lambda_1 t} + a_2 e^{-\lambda_2 t} + a_3$$

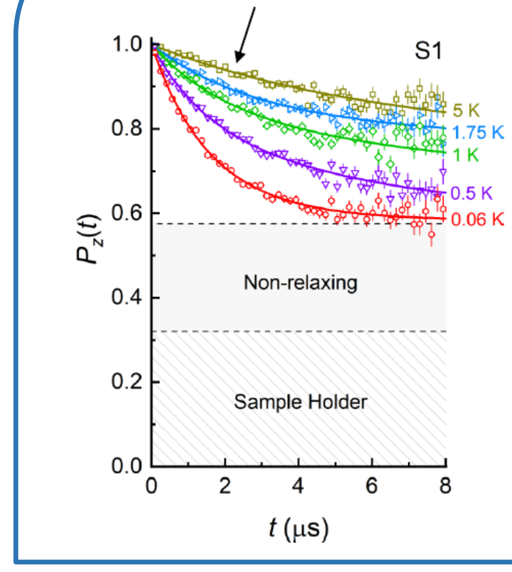

Figure 3: *ZF-μSR spectra of sample S1, for various temperatures.*

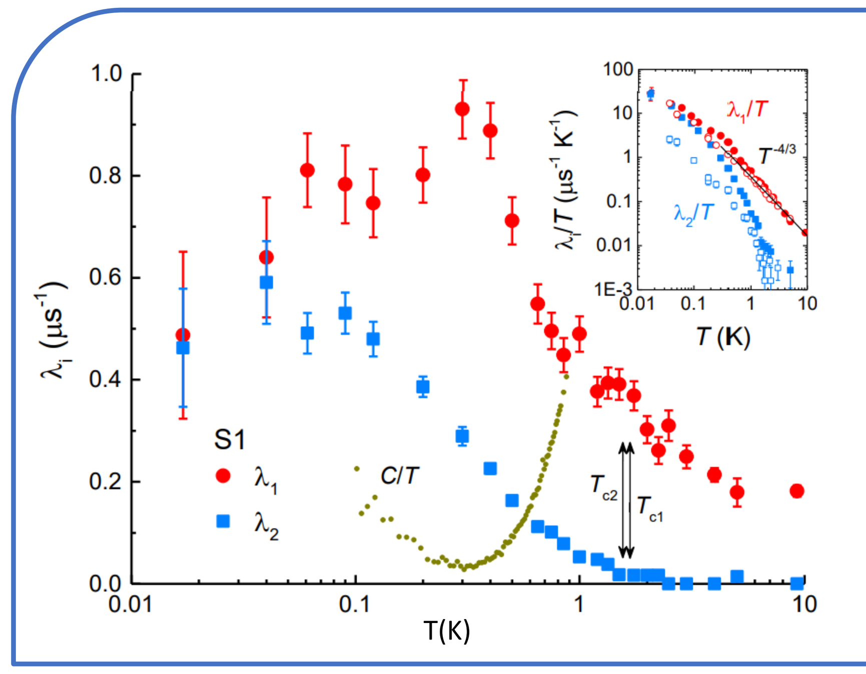

Figure 4: *T* dependence of the ZF exponential relaxation rates for S1 from fits of the ZF-μSR spectra to equation in Fig. 3. The inset shows the T dependence of λ_1/T and λ_2/T for sample S1 (solid symbols) compared to the sample investigated in our earlier study [2].

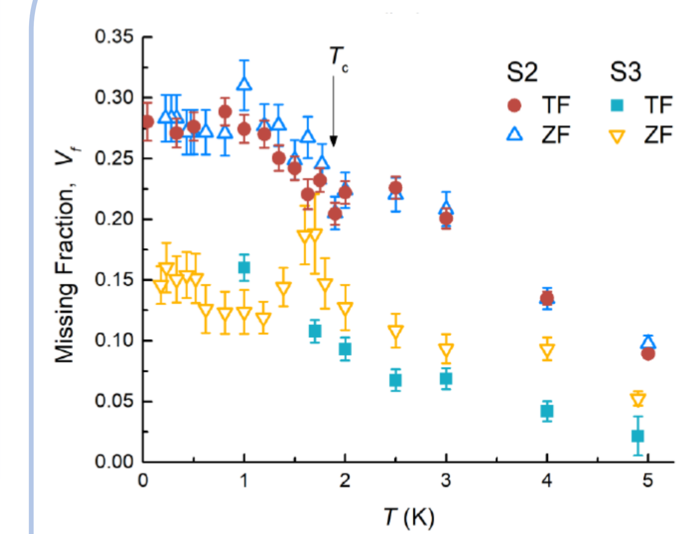

Figure 5: Magnetic volume fraction in c-axis aligned UTe_2 single crystals

Magnetic volume fraction

Fig. 5 shows the temperature dependence of the magnetic volume fraction associated with magnetically-ordered regions in the sample. The growth of the magnetic clusters cease, and the spin dynamics of the clusters change near the onset of superconductivity. Below T_c the slow fluctuating clusters gradually freeze, resulting in a spin frozen state at low temperatures.

Conclusion

A low-temperature *T*-linear term in *C(T)* is a general property of spin glasses, and in UTe_2 is apparently due to clusters of locally ordered spins behaving as spin-glass-like magnetic moments. We attribute the low-*T* upturn in *C(T)/T* to splitting of degenerate ground state nuclear energy levels by internal field created by the magnetic moment of magnetic clusters.

[1] Ran S, Eckberg C, Ding Q-P, Furukawa Y, Metz T, Saha SR, Liu I-L, Zic M, Kim H, Paglione J, and Butch NP, Science 365, 684 (2019);
[2] Sundar, S. et al. Coexistence of ferromagnetic fluctuations and superconductivity in the actinide superconductor UTe2. Phys. Rev. B 100, 140502R (2019).

Discovery, accelerated