Editors' Suggestion

Absence of Spontaneous Magnetic Fields due to Time-Reversal Symmetry Breaking in Bulk Superconducting UTe_2

N. Azari,[1] M. Yakovlev,[1] N. Rye,[1] S. R. Dunsiger,[1,2] S. Sundar,[3] M. M. Bordelon,[4] S. M. Thomas,[4] J. D. Thompson,[4] P. F. S. Rosa,[4] and J. E. Sonier[1]

[1]*Department of Physics, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada*
[2]*Centre for Molecular and Materials Science, TRIUMF, Vancouver, British Columbia V6T 2A3, Canada*
[3]*Scottish Universities Physics Alliance, School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, United Kingdom*
[4]*Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*

(Received 18 August 2023; accepted 18 October 2023; published 29 November 2023)

We have investigated the low-temperature local magnetic properties in the bulk of molten salt-flux (MSF)-grown single crystals of the candidate odd-parity superconductor UTe_2 by zero-field muon spin relaxation (μSR). In contrast to previous μSR studies of UTe_2 single crystals grown by a chemical vapor transport method, we find no evidence of magnetic clusters or electronic moments fluctuating slow enough to cause a discernible relaxation of the zero-field μSR asymmetry spectrum. Consequently, our measurements on MSF-grown single crystals rule out the generation of spontaneous magnetic fields in the bulk that would occur near impurities or lattice defects if the superconducting state of UTe_2 breaks time-reversal symmetry. This result suggests that UTe_2 is characterized by a single-component superconducting order parameter.

DOI: 10.1103/PhysRevLett.131.226504

A superconducting phase results from the condensation of electron (Cooper) pairs into a coherent quantum state characterized by a pair wave function or complex order parameter consisting of an amplitude and a phase. All superconductors break gauge symmetry, which means their order parameter adopts a well-defined phase below the superconducting transition temperature (T_c). Conventional superconductors have a spin-singlet pairing state with an isotropic spatial component (s-wave) mediated by electron-phonon coupling. By contrast, unconventional superconductors deviate from this pairing state and may be characterized by more elaborate superconducting order parameters due to the breaking of additional symmetries [1].

Recently discovered UTe_2 is believed to be a rare example of an unconventional odd-parity superconductor based on an abnormally large upper critical magnetic field (H_{c2}) [2,3], as well as the small change in the nuclear-magnetic resonance (NMR) Knight shift as a function of temperature in the superconducting state [4–6]. The observation of a nonzero polar Kerr effect (PKE) in the superconducting state of chemical vapor transport (CVT)-grown UTe_2 single crystals that exhibit two phase transitions in the specific heat has been taken as evidence of a time-reversal symmetry (TRS)-breaking order parameter [7,8]. Broken TRS is a defining property of chiral superconductivity [9], and, hence, the appearance of the PKE below T_c lends support to other signatures of chiral superconductivity detected by scanning tunneling microscopy (STM) [10] and magnetic penetration depth [11,12] measurements of UTe_2. Chiral odd-parity superconductivity is of much current interest, because certain topological nontrivial Cooper pairing states can host Majorana zero modes with potential applications for topological quantum computing [9,13].

The superconducting order parameter at a second-order phase transition is restricted to an irreducible representation of the total symmetry group [1]. The possible superconducting phases in UTe_2 are, therefore, classified by the crystalline point group symmetry D_{2h}. Order parameters that transform under the one-dimensional irreducible representations (1D irreps) of this group do not break TRS. Consequently, to explain the signature of spontaneous TRS breaking in the polar Kerr measurements and the chiral surface states detected by STM, an odd-parity superconducting order parameter having two nearly degenerate components with a relative phase belonging to different 1D irreps of the D_{2h} crystalline point group has been proposed [7,10]. However, this characterization of the superconducting order parameter for UTe_2 presents a number of challenges. The PKE was observed in a sample showing two phase transitions in the specific heat at ambient pressure, as expected if the two components of the order parameter are nearly degenerate. However, as the quality of the samples improved, only a single superconducting transition was observed [14,15]. A recent study of the PKE in CVT-grown and MSF-grown UTe_2 single crystals that exhibit a single superconducting phase transition in the specific heat found no evidence for TRS breaking superconductivity [16]. Furthermore, pulse-echo ultrasound measurements of the changes in elastic moduli across T_c in single and double phase transition CVT-grown samples [17] and recent NMR Knight shift measurements on MSF-grown UTe_2 single crystals [6] both favor a single-component odd-parity superconducting order parameter.

Zero-field muon spin relaxation (ZF-μSR) is an ideal tool for independently determining whether TRS symmetry is spontaneously broken in a superconducting state. In the bulk of a TRS-breaking superconductor, inhomogeneities of the order parameter that occur near impurities, lattice defects, or around domain walls generate spontaneous currents [18]. The corresponding weak spontaneous local magnetic fields have been detected by ZF-μSR in numerous unconventional superconductors—most notably UPt_3 [19] and Sr_2RuO_4 [20], two compounds in which TRS breaking has been confirmed by polar Kerr measurements [21,22]. Both superconductors have been considered as likely chiral superconductors, although Sr_2RuO_4 is no longer believed to be a candidate for odd-parity superconductivity [23].

As for UTe_2, the relaxation rate of the ZF-μSR signal from CVT-grown single crystals exhibiting single or double transitions in the specific heat was found to be dominated by inhomogeneous freezing of magnetic clusters [24,25], which thwarted sensitivity to the potential onset of weak spontaneous fields at T_c. As discussed in Ref. [25], the magnetic clusters are likely responsible for the residual linear term in the temperature dependence of the specific heat (C) below T_c and the low-temperature upturn in C/T versus T that are ubiquitous in UTe_2 samples grown via the CVT method. Moreover, a saturation in the growth of the total volume of the magnetic clusters and an abrupt slowing down of their fluctuation rate was observed near T_c. By contrast, current UTe_2 single crystals grown by the MSF method have less disorder and, correspondingly, a much larger residual resistivity ratio (RRR) as well as a substantially smaller residual T-linear term in the specific heat compared to CVT-grown single crystals [15]. A potential origin of the magnetic clusters is discussed later, but they are presumably induced by defects that disrupt long-range electronic correlations, as suggested in Ref. [26]. Hence, while MSF-grown UTe_2 single crystals may contain trace amounts of the ferromagnetic (FM) impurities U_7Te_{12} and U_3Te_5 [15], magnetic clusters are expected to be sparse.

Here, we present results of a ZF-μSR study of MSF-grown UTe_2 single crystals. The single crystals all come from the same growth batch and exhibit bulk superconductivity below $T_c = 2.01$ K, as determined from the midpoint of the specific heat jump shown in Fig. 1(a). The crystals have an RRR value of 200, and the coefficient of the residual T-linear term in the specific heat below T_c is approximately 9 $\mathrm{mJ/mol \cdot K^2}$. Figure 1(b) shows a comparison of the temperature dependence of the bulk magnetic susceptibility (χ) for a magnetic field of 1 kOe applied along the three principal crystallographic axes. In contrast to the low-field behavior of $\chi(T)$ along the a axis in

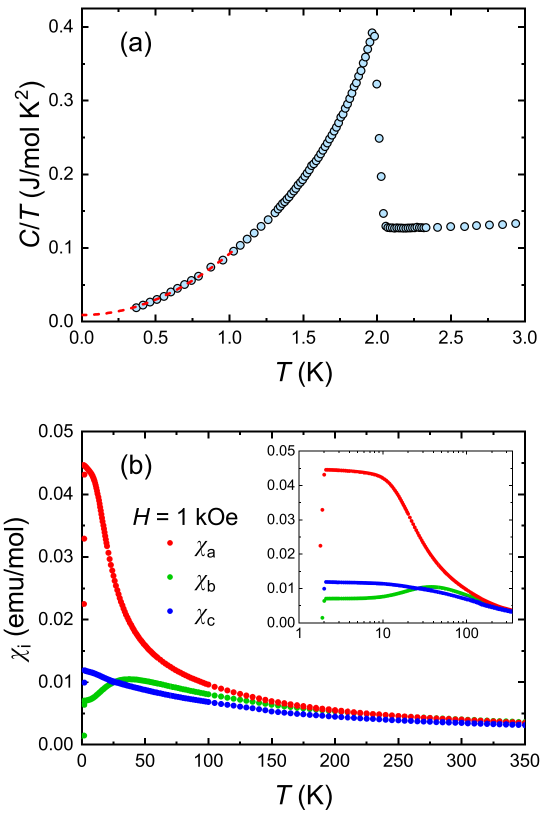

FIG. 1. (a) Temperature dependence of the specific heat (C) for one of the MSF-grown UTe_2 single crystals, plotted as C/T versus T. The dashed curve is a fit of the data below $T = 1$ K to $C/T = \gamma^* + \beta T^2$, which yields $\gamma^* = 9.1(6)$ $\mathrm{mJ/mol\ K^2}$ and $\beta = 83(1)$ $\mathrm{mJ/mol\ K^3}$. (b) Temperature dependence of the bulk magnetic susceptibility of the single crystal for a magnetic field $H = 1$ kOe applied parallel to the three different principal crystallographic axes. The inset shows the same data as a semilogarithmic plot.

CVT-grown UTe_2 single crystals [2,14], $\chi_a(T)$ does not exhibit an upturn below $T \sim 10$ K.

For the ZF-μSR measurements, a mosaic of 24 single crystals was mounted on a 5×17 mm pure silver (Ag) backing plate thermally anchored to the Ag sample holder of an Oxford Instruments top-loading dilution refrigerator at the end of the M15 surface muon beam line at TRIUMF, Vancouver, Canada. The MSF-grown UTe_2 single crystals covered 83% of the Ag backing plate. The c axis of each single crystal was aligned within 2° of the normal of the Ag backing plate. For the zero-field measurements, stray external magnetic fields at the sample position were reduced to $\lesssim 41$ mG using field compensation coils and the precession signal of muonium ($\mathrm{Mu} \equiv \mu^+ e^-$) in intrinsic Si as a sensitive magnetometer [27]. The ZF-μSR measurements were performed by implanting nearly 100% spin-polarized positive muons (μ^+) into the sample with the initial muon spin polarization $\mathbf{P}(0)$ antiparallel to the muon beam direction (defined as the z-axis direction) and parallel to the crystalline c axis. The time evolution of the muon spin polarization $P_z(t)$ was determined by detecting the muon decay positrons in a pair of opposing detectors positioned outside of the dilution refrigerator in front and behind the sample.

The ZF-μSR asymmetry spectra are well described by the following equation:

$$A(t) = a_0 P_z(t) = a_1 G_z^{\mathrm{GKT}}(\Delta, t) e^{-\lambda_1 t} + a_2 e^{-\lambda_2 t}, \quad (1)$$

where $G_z^{\mathrm{GKT}}(\Delta, t)$ is a static Gaussian Kubo-Toyabe (GKT) function, characterized by the linewidth Δ/γ_μ ($\gamma_\mu/2\pi$ is the muon gyromagnetic ratio) of a Gaussian distribution of local magnetic fields [28]. Figure 2 shows a comparison of ZF-μSR asymmetry spectra for $T = 4$ K recorded for measurements of the Ag backing plate with and without the MSF-grown UTe_2 single crystals. The observed relaxation of the ZF-μSR signal with time for the Ag plate without the sample is due to muons landing in material elsewhere within the dilution refrigerator. This contribution is described by the first term in Eq. (1), which makes up

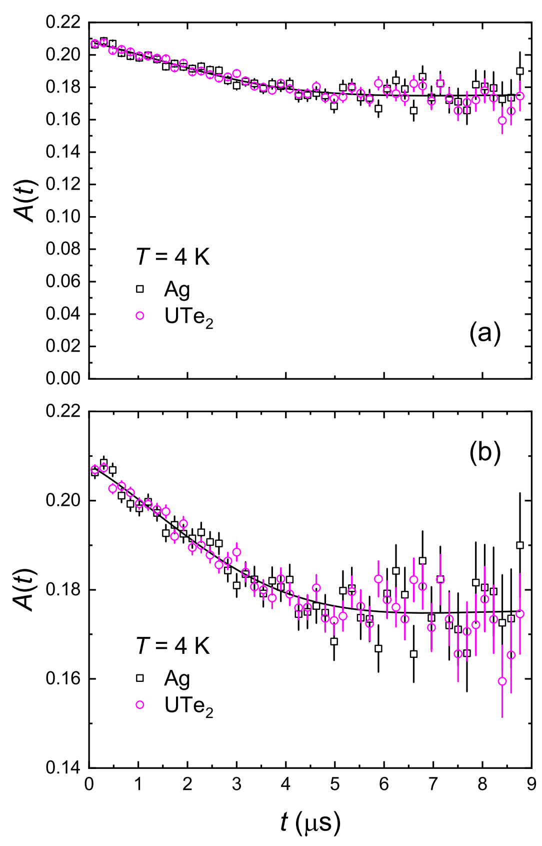

FIG. 2. (a) Comparison of the ZF-μSR asymmetry spectra for the Ag backing plate with (open circles) and without (open squares) the MSF-grown UTe_2 single crystals. The solid curve is a fit of the ZF-μSR spectrum for the Ag plate to Eq. (1). (b) The same as (a) but showing an enlargement on the vertical axis.

$\sim$16% of the total ZF-μSR signal ($a_1/a_0 \sim 16\%$). The remaining 84% of the ZF-μSR asymmetry spectrum is due to muons stopping in the Ag plate ($\sim$64%) and a portion of the Ag sample holder ($\sim$20%). This component of the ZF-μSR signal is essentially nonrelaxing ($\lambda_2 \sim 0$), as Ag does not possess electronic moments and has only very small nuclear moments that do not cause an appreciable muon spin depolarization in the data time window. The relaxation of the ZF-μSR signal by randomly oriented nuclear moments is also negligible in UTe_2, because the only stable uranium isotope with nonzero nuclear spin is depleted ^{235}U, which has a natural abundance of 0.20%, and the natural abundance of the tellurium isotopes with nuclear spin, ^{123}Te and ^{125}Te, is only 0.89% and 7%, respectively. No discernible difference is observed between the ZF-μSR spectra for the Ag plate and the UTe_2 single crystals mounted on the Ag plate, indicating that there are no electronic moments fluctuating in the UTe_2 sample at this temperature that are slow enough to cause additional relaxation of the ZF-μSR signal. With the sample in place, the nonrelaxing component is due to muons stopping in the UTe_2 single crystals, in the Ag backing plate, and in a portion of the Ag sample holder. These contributions are separable in a transverse-field (TF) μSR measurement, due to a sizable muon Knight shift in UTe_2 [29]. The contribution of the UTe_2 sample to the nonrelaxing part of the asymmetry spectrum is estimated to be at least 63% (or 53% of the total ZF-μSR signal) from TF-μSR measurements for an applied magnetic field of 20 kOe.

The ZF-μSR asymmetry spectrum for the UTe_2 sample was recorded for 19 different temperatures between $T = 0.03$ K and $T = 4.0$ K. A global fit of the corresponding 19 different ZF-μSR spectra to Eq. (1) was carried out with the fit parameters a_1, a_2, λ_1, and Δ being shared parameters for all temperatures. The global fit yielded the values $a_1/a_0 = 16.1(7)\%$, $a_2/a_0 = 83.9(7)\%$, $\lambda_1 = 0.158(7)\ \mu\mathrm{s}^{-1}$, and $\Delta = 0.280(7)\ \mu\mathrm{s}^{-1}$. Representative fits to ZF-μSR asymmetry spectra included in the global fit are shown in Fig. 3(a), and the temperature dependence of the exponential relaxation rate λ_2 generated from the global fit is shown in Fig. 3(b). There is no systematic increase in λ_2 with decreasing temperature, in marked contrast to previous observations for CVT-grown single crystals [24,25]. Hence, there are no electronic moments fluctuating slow enough to cause a detectable relaxation of the ZF-μSR spectrum. More importantly, there is no increase in λ_2 near T_c and, hence, no evidence of spontaneous magnetic fields in the bulk associated with a TRS-broken superconducting state.

Extremely slow intra-U-ladder FM fluctuations along the a axis have been inferred from NMR experiments on CVT-grown single crystals [26,30,31] that are far below the rate of spin fluctuations probed in inelastic neutron scattering studies [32,33]. The low-energy FM spin fluctuations may be a consequence of vacancies in the U-ladder structure associated with a small U deficiency in some

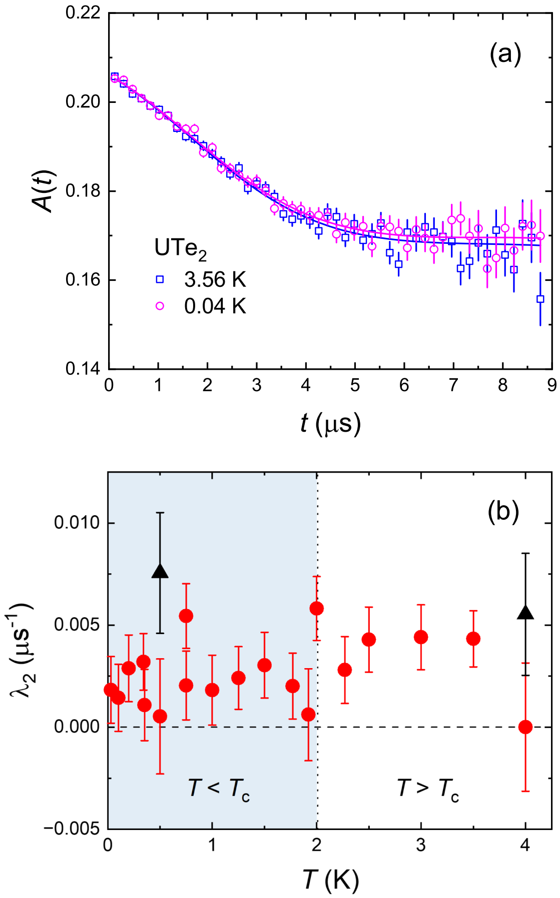

FIG. 3. (a) Comparison of the ZF-μSR asymmetry spectra recorded for the MSF-grown UTe_2 single crystals at $T = 3.56$ K and $T = 0.04$ K. The solid curves are fits of the ZF-μSR spectra to Eq. (1) obtained from a global fit of the ZF-μSR spectra at all temperatures with a_1, a_2, λ_1, and Δ as shared fitting parameters. (b) Temperature dependence of λ_2 obtained from the global fit described in (a). The solid black triangles are values of λ_2 for the Ag backing plate without the sample from fits assuming the same values of λ_1 and Δ generated by the global fit.

CVT-grown UTe_2 samples [15]. In particular, spins next to U vacancies may couple more strongly to the remaining neighboring spins [34], creating slowly fluctuating magnetic clusters that are detectable on the timescales of the NMR and μSR measurements. However, it is clear from the current findings that the FM-like fluctuations observed in our initial ZF-μSR study of CVT-grown single crystals [24] are not detectable in the absence of significant disorder. Consequently, it is an open question as to whether FM fluctuations are an intrinsic property of UTe_2.

In summary, the main result of our ZF-μSR study of MSF-grown single crystals is the absence of spontaneous local magnetic fields in the bulk, which are expected for a superconducting state that breaks TRS. This is in agreement with recent polar Kerr [16], ultrasound [17], and NMR [6] measurements that do not support a two-component superconducting order parameter.

We thank the personnel of the Centre for Molecular and Materials Science at TRIUMF for technical assistance with our μSR measurements. J. E. S. and S. R. D. acknowledge support from the Natural Sciences and Engineering Research Council (NSERC) of Canada (PIN: 146772). S. S. acknowledges support from the Engineering and Physical Sciences Research Council (EPSRC) through Grant No. EP/P024564/1. Work at Los Alamos National Laboratory by S. M. T., J. D. T., and P. F. S. R. was supported by the U.S. Department of Energy, and the Office of Basic Energy Sciences, Division of Materials Science. M. M. B. acknowledges support from the Laboratory Directed Research and Development program.

[1] M. Sigrist and K. Ueda, Phenomenological theory of unconventional superconductivity, Rev. Mod. Phys. **63**, 239 (1991).
[2] S. Ran, C. Eckberg, Q.-P. Ding, Y. Furukawa, T. Metz, S. R. Saha, I.-L. Liu, M. Zic, H. Kim, J. Paglione, and N. P. Butch, Newly ferromagnetic spin-triplet superconductivity, Science **365**, 684 (2019).
[3] D. Aoki, A. Nakamura, F. Honda, D. Li, Y. Homma, Y. Shimizu, Y. J. Sato, G. Knebel, J.-P. Brison, A. Pourret, D. Braithwaite, G. Lapertot, Q. Niu, M. Vališka, H. Harima, and J. Flouquet, Unconventional superconductivity in heavy fermion UTe_2, J. Phys. Soc. Jpn. **88**, 043702 (2019).
[4] G. Nakamine, S. Kitagawa, K. Ishida, Y. Tokunaga, H. Sakai, S. Kambe, A. Nakamura, Y. Shimizu, Y. Homma, D. Li, F. Honda, and D. Aoki, Superconducting properties of heavy fermion UTe_2 revealed by ^{125}Te-nuclear magnetic resonance, J. Phys. Soc. Jpn. **88**, 113703 (2019).
[5] H. Fujibayashi, G. Nakamine, K. Kinjo, S. Kitagawa, K. Ishida, Y. Tokunaga, H. Sakai, S. Kambe, A. Nakamura, Y. Shimizu, Y. Homma, D. Li, F. Honda, and D. Aoki, Superconducting order parameter in UTe_2 determined by Knight shift measurement, J. Phys. Soc. Jpn. **91**, 043705 (2022).
[6] H. Matsumura, H. Fujibayashi, G. Nakamine, K. Kinjo, S. Kitagawa, K. Ishida, Y. Tokunaga, H. Sakai, S. Kambe, A. Nakamura, Y. Shimizu, Y. Homma, D. Li, F. Honda, and D. Aoki, Large reduction in the *a*-axis knight shift on UTe_2 with $T_c = 2.1$ K, J. Phys. Soc. Jpn. **92**, 063701 (2023).
[7] I. M. Hayes, D. S. Wei, T. Metz, J. Zhang, Y. S. Eo, S. Ran, S. R. Saha, J. Collini, N. P. Butch, D. F. Agterberg, A. Kapitulnik, and J. Paglione, Multicomponent superconducting order parameter in UTe_2, Science **373**, 797 (2021).
[8] D. S. Wei, D. Saykin, O. Y. Miller, S. Ran, S. R. Saha, D. F. Agterberg, J. Schmalian, N. P. Butch, J. Paglione, and A. Kapitulnik, Interplay between magnetism and superconductivity in UTe_2, Phys. Rev. B **105**, 024521 (2022).
[9] C. Kallin and J. Berlinsky, Chiral superconductors, Rep. Prog. Phys. **79**, 054502 (2016).
[10] L. Jiao, S. Howard, S. Ran, Z. Wang, J. O. Rodriguez, M. Sigrist, Z. Wang, N. P. Butch, and V. Madhavan, Chiral superconductivity in heavy-fermion metal UTe_2, Nature (London) **579**, 523 (2020).
[11] S. Bae, H. Kim, Y. S. Eo, S. Ran, I.-L. Liu, W. T. Fuhrman, J. Paglione, N. P. Butch, and S. M. Anlage, Anomalous

normal fluid response in a chiral superconductor UTe_2, Nat. Commun. **12**, 2644 (2021).

[12] K. Ishihara, M. Roppongi, M. Kobayashi, K. Imamura, Y. Mizukami, H. Sakai, P. Opletal, Y. Tokiwa, Y. Haga, K. Hashimoto, and T. Shibauchi, Chiral superconductivity in UTe_2 probed by anisotropic low-energy excitations, Nat. Commun. **14**, 2966 (2023).

[13] S. Das Sarma, M. Freedman, and C. Nayak, Majorana zero modes and topological quantum computation, npj Quantum Inf. **1**, 15001 (2015).

[14] P. F. S. Rosa, A. Weiland, S. S. Fender, B. L. Scott, F. Ronning, J. D. Thompson, E. D. Bauer, and S. M. Thomas, Single thermodynamic transition at 2 K in superconducting UTe_2 single crystals, Commun. Mater. **3**, 1 (2022).

[15] H. Sakai, P. Opletal, Y. Tokiwa, E. Yamamoto, Y. Tokunaga, S. Kambe, and Y. Haga, Single crystal growth of superconducting UTe_2 by molten salt flux method, Phys. Rev. Mater. **6**, 073401 (2022).

[16] M. O. Ajeesh, M. Bordelon, C. Girod, S. Mishra, F. Ronning, E. D. Bauer, B. Maiorov, J. D. Thompson, P. F. S. Rosa, and S. M. Thomas, The fate of time-reversal symmetry breaking in UTe_2, Phys. Rev. X **13**, 041019 (2023).

[17] F. Theuss, A. Shragai, G. Grissonnanche, I. M. Hayes, S. R. Saha, Y. S. Eo, A. Suarez, T. Shishidou, N. P. Butch, J. Paglione, and B. J. Ramshaw, Single-component superconductivity in UTe_2 at ambient pressure, arXiv:2307.10938.

[18] M. Sigrist, Time-reversal symmetry breaking states in high-temperature superconductors, Prog. Theor. Phys. **99**, 899 (1998).

[19] G. M. Luke, A. Keren, L. P. Le, W. D. Wu, Y. J. Uemura, D. A. Bonn, L. Taillefer, and J. D. Garrett, Muon spin relaxation in UPt_3, Phys. Rev. Lett. **71**, 1466 (1993).

[20] G. M. Luke, Y. Fudamoto, K. M. Kojima, M. I. Larkin, J. Merrin, B. Nachumi, Y. J. Uemura, Y. Maeno, Z. Q. Mao, Y. Mori, H. Nakamura, and M. Sigrist, Time-reversal symmetry-breaking superconductivity in Sr_2RuO_4, Nature (London) **394**, 558 (1998).

[21] J. Xia, Y. Maeno, P. T. Beyersdorf, M. M. Fejer, and A. Kapitulnik, High resolution polar Kerr effect measurements of Sr_2RuO_4: Evidence for broken time-reversal symmetry in the superconducting state, Phys. Rev. Lett. **97**, 167002 (2006).

[22] E. R. Schemm, W. J. Gannon, C. M. Wishne, W. P. Halperin, and A. Kapitulnik, Observation of broken time-reversal symmetry in the heavy-fermion superconductor UPt_3, Science **345**, 190 (2014).

[23] A. Chronister, A. Pustogow, N. Kikugawa, D. A. Sokolov, F. Jerzembeck, C. W. Hicks, A. P. Mackenzie, E. D. Bauer, and S. E. Brown, Evidence for even parity unconventional superconductivity in Sr_2RuO_4, Proc. Natl. Acad. Sci. U.S.A. **118**, e2025313118 (2021).

[24] S. Sundar, S. Gheidi, K. Akintola, A. M. Côté, S. R. Dunsiger, S. Ran, N. P. Butch, S. R. Saha, J. Paglione, and J. E. Sonier, Coexistence of ferromagnetic fluctuations and superconductivity in the actinide superconductor UTe_2, Phys. Rev. B **100**, 140502(R) (2019).

[25] S. Sundar, N. Azari, M. R. Goeks, S. Gheidi, M. Abedi, M. Yakovlev, S. R. Dunsiger, J. M. Wilkinson, S. J. Blundell, T. E. Metz, I. M. Hayes, S. R. Saha, S. Lee, A. J. Woods, R. Movshovich, S. M. Thomas, N. P. Butch, P. F. S. Rosa, J. Paglione, and J. E. Sonier, Ubiquitous spin freezing in the superconducting state of UTe_2, Commun. Phys. **6**, 24 (2023).

[26] Y. Tokunaga, H. Sakai, S. Kambe, Y. Haga, Y. Tokiwa, P. Opletal, H. Fujibayashi, K. Kinjo, S. Kitagawa, K. Ishida, A. Nakamura, Y. Shimizu, Y. Homma, D. Li, F. Honda, and D. Aoki, Slow electronic dynamics in the paramagnetic state of UTe_2, J. Phys. Soc. Jpn. **91**, 023707 (2022).

[27] G. D. Morris and R. H. Heffner, A method of achieving accurate zero-field conditions using muonium, Physica (Amsterdam) **326B**, 252 (2003).

[28] R. S. Hayano, Y. J. Uemura, J. Imazato, N. Nishida, T. Yamazaki, and R. Kubo, Zero- and low-field spin relaxation studied by positive muons, Phys. Rev. B **20**, 850 (1979).

[29] N. Azari, M. R. Goeks, M. Yakovlev, M. Abedi, S. R. Dunsiger, S. M. Thomas, J. D. Thompson, P. F. S. Rosa, and J. E. Sonier, μ^+ knight shift in UTe_2: Evidence for relocalization in a kondo lattice, Phys. Rev. B **108**, L081103 (2023).

[30] D. V. Ambika, Q.-P. Ding, K. Rana, C. E. Frank, E. L. Green, S. Ran, N. P. Butch, and Y. Furukawa, Possible coexistence of antiferromagnetic and ferromagnetic spin fluctuations in the spin-triplet superconductor UTe_2 revealed by ^{125}Te NMR under pressure, Phys. Rev. B **105**, L220403 (2022).

[31] H. Fujibayashi, K. Kinjo, G. Nakamine, S. Kitagawa, K. Ishida, Y. Tokunaga, H. Sakai, S. Kambe, A. Nakamura, Y. Shimizu, Y. Homma, D. Li, F. Honda, and D. Aoki, Low-temperature magnetic fluctuations investigated by ^{125}Te-NMR on the uranium-based superconductor UTe_2, J. Phys. Soc. Jpn. **92**, 053702 (2023).

[32] C. Duan, K. Sasmal, M. B. Maple, A. Podlesnyak, J.-X. Zhu, Q. Si, and P. Dai, Incommensurate spin fluctuations in the spin-triplet superconductor candidate UTe_2, Phys. Rev. Lett. **125**, 237003 (2020).

[33] W. Knafo, G. Knebel, P. Steffens, K. Kaneko, A. Rosuel, J.-P. Brison, J. Flouquet, D. Aoki, G. Lapertot, and S. Raymond, Low-dimensional antiferromagnetic fluctuations in the heavy-fermion paramagnetic ladder compound UTe_2, Phys. Rev. B **104**, L100409 (2021).

[34] M. Laukamp, G. B. Martins, C. Gazza, A. L. Malvezzi, E. Dagotto, P. M. Hansen, A. C. López, and J. Riera, Enhancement of antiferromagnetic correlations induced by nonmagnetic impurities: Origin and predictions for NMR experiments, Phys. Rev. B **57**, 10755 (1998).