Highlights

RESEARCH AREA 1 - Superconductors and Innovative materials for Energy and Environment - 2023

"Calorimetric evidence for two phase transitions in $Ba_{1-x}K_xFe_2As_2$ with fermion pairing and quadrupling states"

I. Shipulin[1,6], N. Stegani[2,7], I. Maccari[3], K. Kihou[4], C. Lee[4], Q. Hu[5], Y. Zheng[5], F. Yang[5], Y. Li[5], C. Yim[5], R. Huhne[1], H. Klauss[6], M. Putti[2,7], F. Caglieris[7], E. Babaev[3], V. Grinenko[5]

[1]Institute for Metallic Materials, Leibniz-IFW Dresden, D-01069, Dresden, Germany
[2]University of Genoa, Via Dodecaneso 33, 16146, Genoa, Italy
[3]Department of Physics, KTH Royal Institute of Technology, SE-106 91, Stockholm, Sweden
[4]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568, Japan
[5]Tsung-Dao Lee Institute, Shanghai Jiao Tong University, Shanghai, 201210, China
[6]Institute for Solid State and Materials Physics, Technische Universität Dresden, D-01069, Dresden, Germany
[7]Consiglio Nazionale delle Ricerche (CNR)-SPIN, Corso Perrone 24, 16152, Genova, Italy

Nature Communications **volume 14, Article number: 6734 (2023)**

In the phase diagram of $Ba_{1-x}K_xFe_2As_2$, many studies claimed the existence of a Lifshitz transition tuned by K doping around x=0.75, which involves the change of the gap structure from the original s± symmetry, to a s- or d- wave symmetry, passing by an intermediate region where time reversal symmetry is broken and the superconducting order parameter becomes complex (s+is or s+id). S+is superconductors exhibit a range of unconventional properties, and the time-reversal symmetry breaking (BTRS) is mostly manifested in spontaneous currents around nonmagnetic impurities, that result in local magnetic fields. The BTRS state sets in at T_c^{Z2}, and beyond the mean field approximation, a situation in which $T_c > T_c^{Z2}$ can arise, implying the existence of a bosonic metallic non-superconducting state above T_c, in which time-reversal symmetry is broken.
In this work, a combination of specific heat and spontaneous Nernst effect measurements have been performed in order to prove the presence of a bosonic BTRS state in Ba-122, at $T_c^{Z2} > T_c$. The specific heat data DeltaCel/T, presented in fig. 1, exhibit the superconducting phase transition at T_c, followed by a step-like anomaly above Tc highlighted by the black arrow. This anomaly cannot be caused by superconducting phases surviving at higher temperatures since no superconducting signal is observed in the magnetic susceptibility (blue curves). To investigate whether this anomaly can be associated with the BTRS state, the specific heat has been compared with spontaneous Nernst effect (SNE) (fig. 2). A SNE signal ≠0 appears at T_c^{Z2}=13.25K, highlighted by the vertical green dashed line, and coincides with the high-temperature anomaly in the specific heat. These observations commonly agree in detecting the breaking of time-reversal symmetry at TcZ2 and allow to confirm the existence of a bosonic metallic state in the range $T_c < T < T_c^{Z2}$ in $Ba_{1-x}K_xFe_2As_2$.

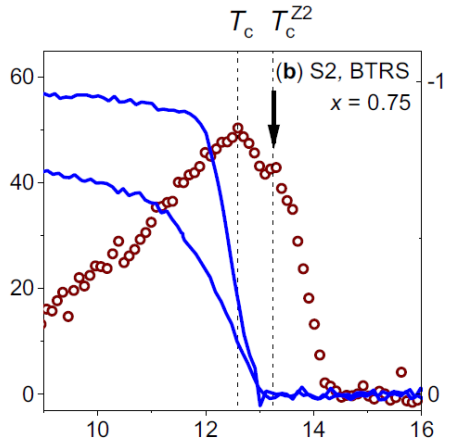

Fig. 1: Specific heat (red dots) and magnetic susceptibility (blue curves) of $Ba_{1-x}K_xFe_2As_2$ with x=0.75. The vertical black arrow indicates T_c^{Z2}.

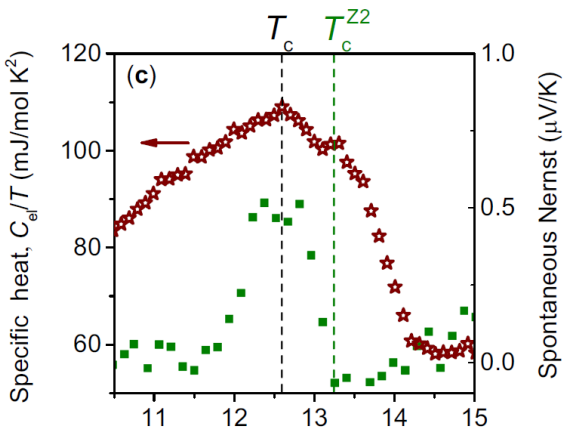

Fig. 2: Specific heat (left-axes) and Spontaneous Nernst effect (right-axes) of $Ba_{1-x}K_xFe_2As_2$ with x=0.75.

Consiglio Nazionale delle Ricerche
SPIN