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Metal State with Spontaneously Broken Time-Reversal Symmetry above the Superconducting Phase Transition

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Fundamentally, what distinguishes a superconducting state from a normal state is a spontaneously broken symmetry corresponding to the long-range coherence of Cooper pairs, leading to zero resistivity and diamagnetism.

Here we report a set of thermodynamic, transport and muon spectroscopy observations on a series of hole-doped $Ba_{1-x}K_xFe_2As_2$. Our specific-heat measurements indicate the formation of fermionic bound states when the temperature is lowered from the normal state. However, at the doping level $x \approx 0.8$, instead of the characteristic onset of diamagnetic screening and zero resistance expected below a superconducting phase transition (T_c), we observe the opposite effect: the generation of self-induced magnetic fields in the resistive state, measured by spontaneous Nernst effect 1 and muon spin rotation experiments [2,3] (see Fig.1). This combined evidence indicates the existence of a bosonic metal state in the temperature range $T_c \leq T \leq T_{Z2}$ in which Cooper pairs of electrons lack coherence, but the system spontaneously breaks time-reversal symmetry (Z2). The observations are consistent with the theory of a state with fermionic quadrupling, in which long-range order exists not between Cooper pairs but only between *pairs of pairs*.

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$_{Z2}$1[V. Grinenko et al., Nat. Phys. 17, 1254–1259 (2021).
]2[V. Grinenko et al., Phys. Rev. B 95, 214511 (2017).
]3[V. Grinenko et al., Nat. Phys. 16, 789–794 (2020).

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