

Thermoelectricity evidence for quantum criticality in clean infinite-layer nickelate films

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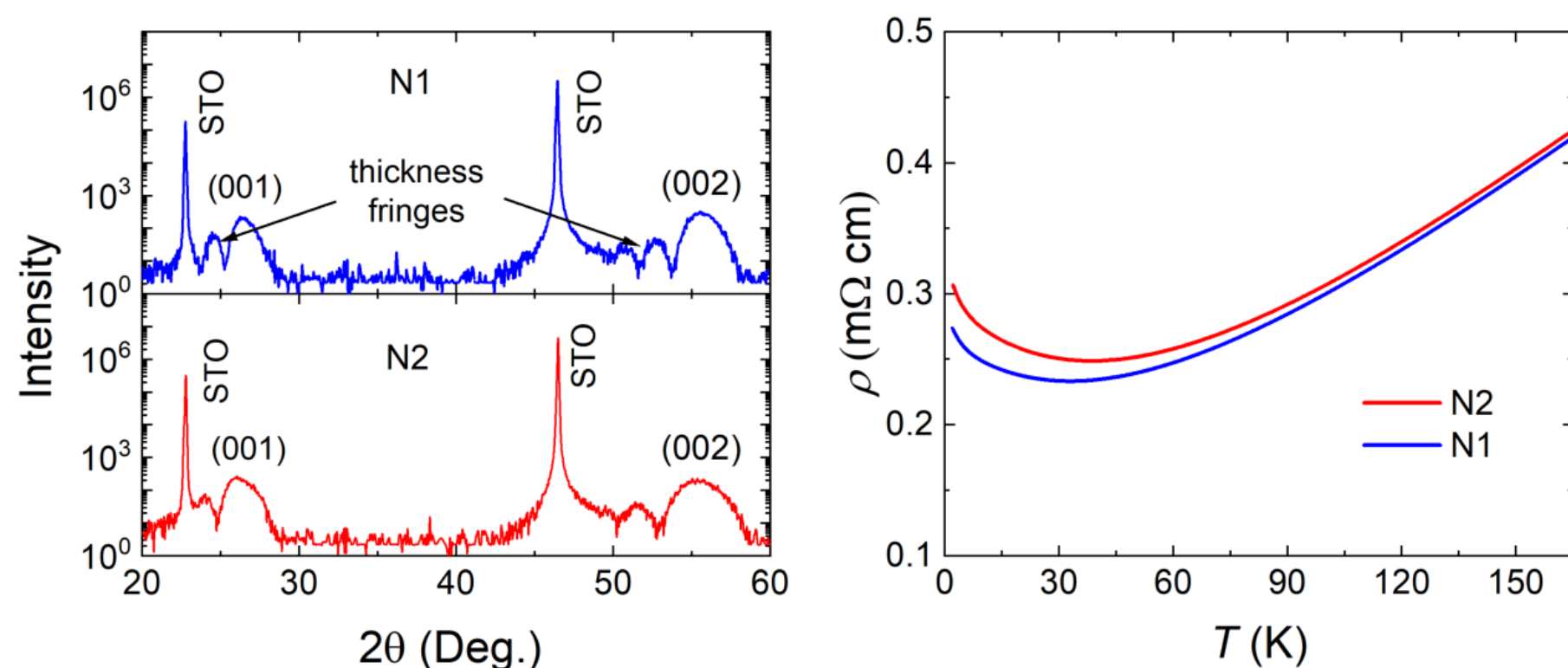
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Introduction

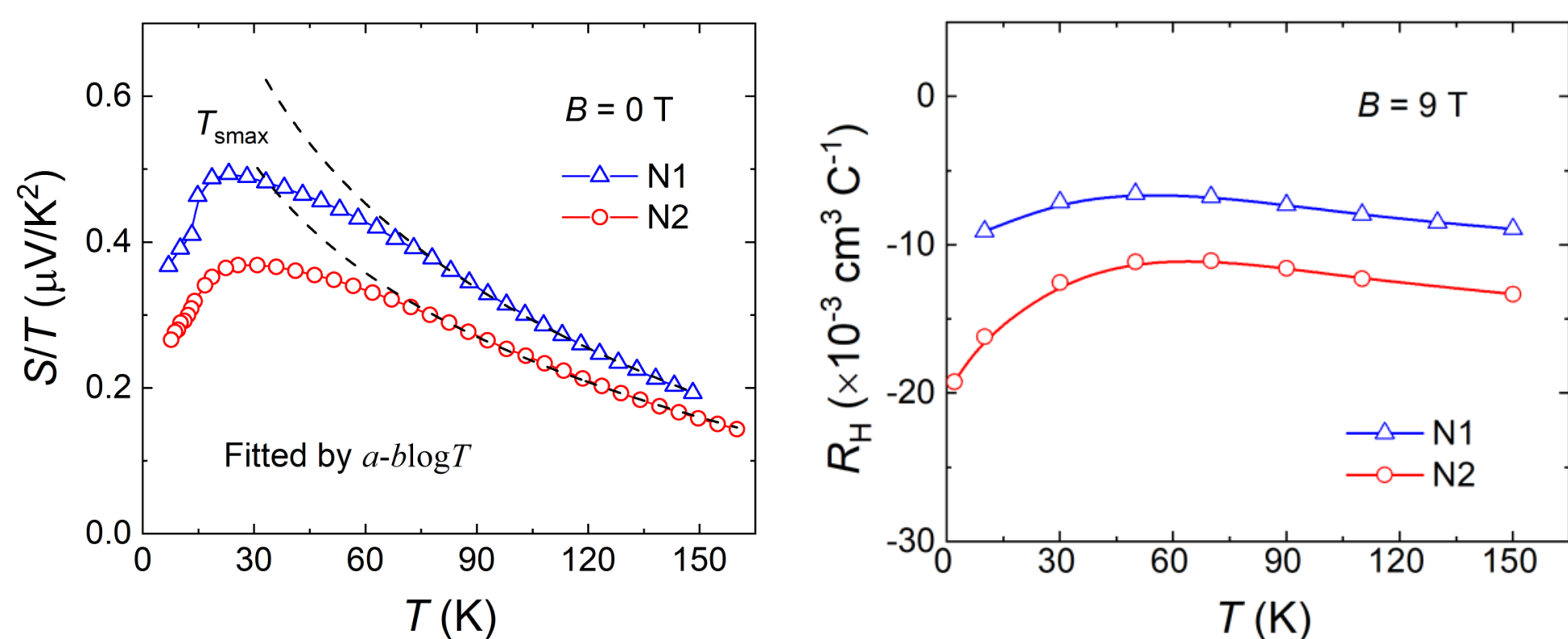
Quantum criticality has become a central paradigm for understanding unconventional superconductivity. However, its manifestation in the newly discovered family of nickelates [1] remains largely unexplored. Recently, linear-in-temperature resistivity, a hallmark of quantum critical behavior often linked to the "strange metal" state in cuprates [2,3] and iron-based superconductors [4], was reported in nearly optimally doped $\text{Nd}_{1-x}\text{Sr}_x\text{NiO}_2$ [5], hinting at a possible convergence of quantum criticality across different unconventional superconducting families. In this work, we investigate the thermopower-to-temperature ratio (S/T) in parent NdNiO_2 (NNO) and $\text{Sm}_{0.95-x}\text{Ca}_{0.05}\text{Eu}_x\text{NiO}_2$ (SCE_x) films. Our results reveal that quantum critical behavior indeed exists in infinite-layer nickelates and is intimately correlated with the superconducting transition temperature (T_c).

1. Cleaner NNO films



- Infinite-layer nickelate NdNiO_2 samples were obtained by reducing NdNiO_3 films deposited on SrTiO_3 (001).
- Clear thickness fringes in the XRD patterns of two samples indicate the successful fabrication of a high-quality infinite-layer phase, which is further corroborated by the resistivity data. Specifically, the minimum resistivities (ρ_{\min}) are 0.23 mΩ cm for N1 and 0.25 mΩ cm for N2—one order of magnitude lower than previously reported values (Ref. [1]).

2. Quantum criticality in clean NNO films



- In clean samples, the opposite signs of thermopower (S) and Hall coefficient (R_H) indicate that thermopower are governed by quantum criticality rather than band theory. Similar behavior has been reported for the n - and p -type cuprates [6, 7].

Significance

$$S = -\frac{\pi^2 k_B^2 T}{3e} \left[\frac{\partial \ln \tau}{\partial \epsilon} \right]_{\epsilon_F} + \frac{3}{2\epsilon_F} \quad \& \quad R_H \sim \frac{1}{en}$$

Here, $1/\tau_t = 1/\tau_0 + 1/\tau_{\text{SMFL}}(\epsilon, T)$

In clean limit: $1/\tau_t \approx 1/\tau_{\text{SMFL}}$, $S/T \sim -\log T$

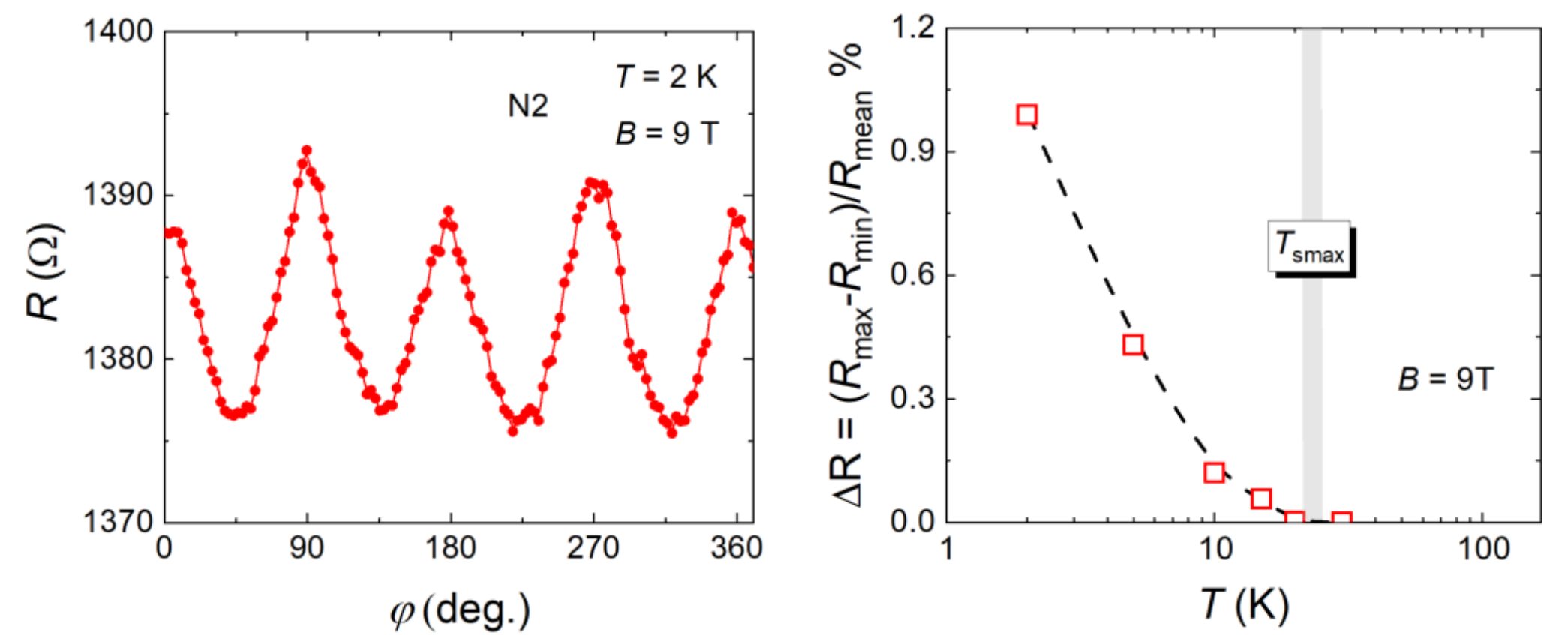
In dirty limit: $1/\tau_t \approx 1/\tau_0$, So, $S/T = -\frac{\pi^2 k_B^2}{3e\epsilon_F}$

This is the main reason for the deviation of S/T and R_H in clean films!

Summary

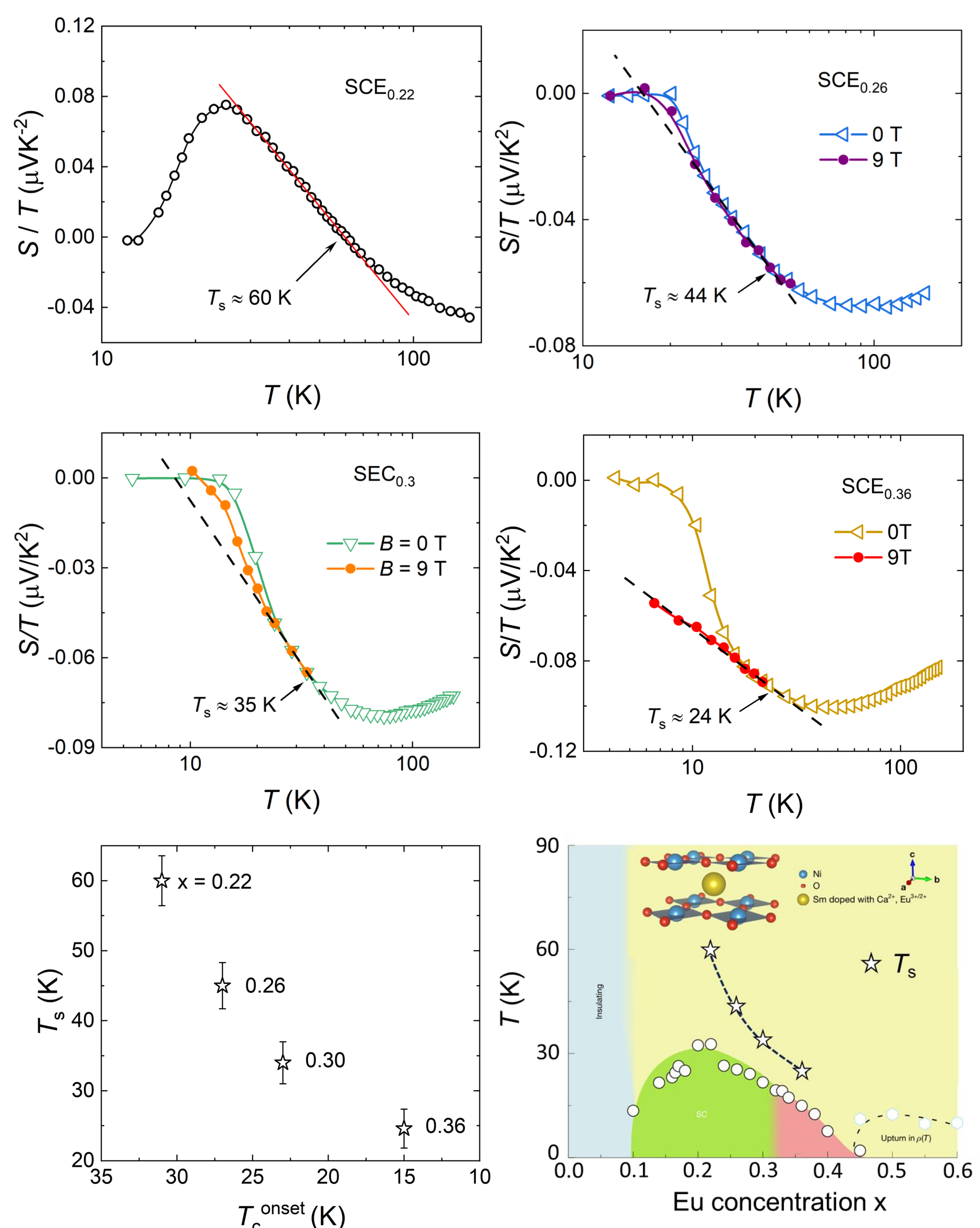
Our work demonstrates that quantum criticality exists in infinite-layer nickelates and is intimately linked to T_c as evidenced by logarithmic S/T . These findings emphasize the importance of quantum critical behavior in proximity to QCP in infinite-layer nickelates and further suggest a convergence of such behavior across different unconventional superconducting families.

3. Four-fold symmetry breaking in NNO



- Angle-dependent magnetoresistance measurements were performed on NNO film as it was rotated around the c -axis with $H \parallel ab$. A clear four-fold symmetry emerges at 2 K under 9 T.
- The temperature-dependent ΔR indicates that the four-fold symmetry breaking originates from spin ordering rather than lattice symmetry.
- The temperature at which this symmetry disappears is consistent with T_{smax} , the temperature where S/T reaches its maximum value.

4. Logarithmic behavior of S/T in SCE_x films



- Above T_c , the S/T of $\text{SCE}_{0.22}$ exhibits a $\log T$ dependence, but deviates from this behavior at T_s .
- A similar logarithmic divergence also emerges in overdoped samples once superconductivity is suppressed by a magnetic field.
- The positive correlation between T_s and T_c highlights the role of quantum critical behavior in nickelate superconductors. Lower-right panel: phase diagram from Ref. [8]; stars: our data (this work).
- Overall, our findings indicate that nickelates exhibit quantum critical behavior akin to that observed in cuprates.