Intrinsic Bulk Superconductivity in Undoped $PrNiO_2$ as a Distinct Superconducting Regime

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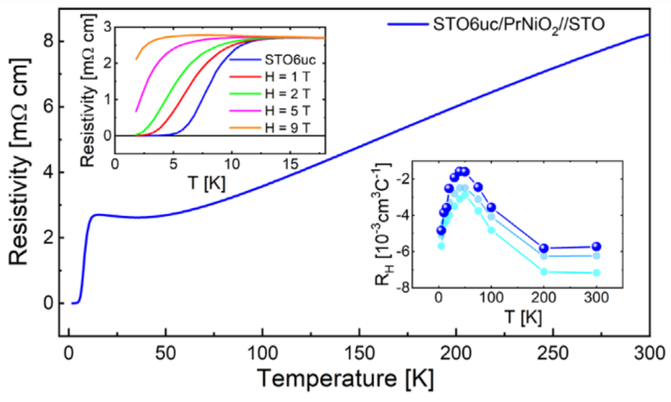
Complex Quantum Materials Group

What is the origin of superconductivity in the undoped infinite-layer (IL) nickelates?

Anomalous superconductivity in undoped $PrNiO_2$ and $NdNiO_2$

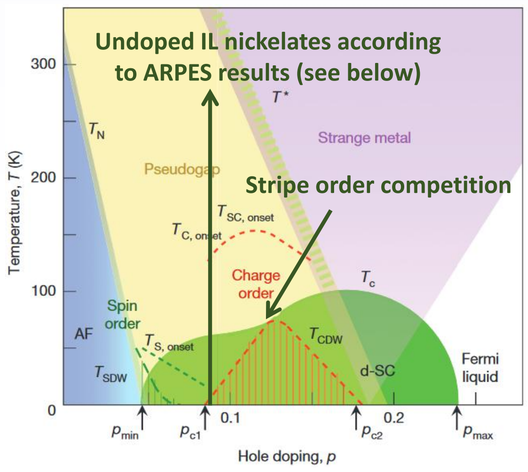
*STO capped. Is that necessary?



Sahib H et al., *Adv. Mater.,* **37**(16): 2416187(2025).

C. T. Parzyck et al., *PRX* **15**, 021048 (2025).

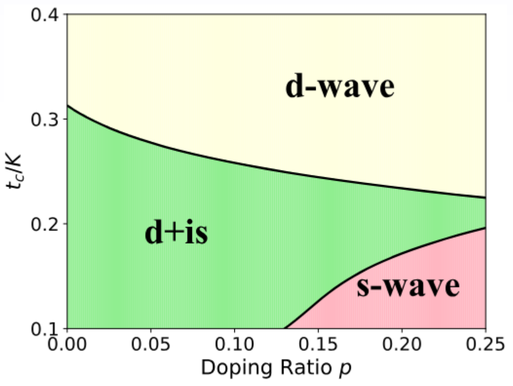
Doping level of undoped IL nickelates are in SC dome of cuprates



Keimer B. et al., *Nature* **518**(7538): 179-186(2015).

Possible different pairing symmetries in the underdoped regime

d+*is* in the underdoped regime



Wang et al., *PRB* **102**, 220501(R) (2020).

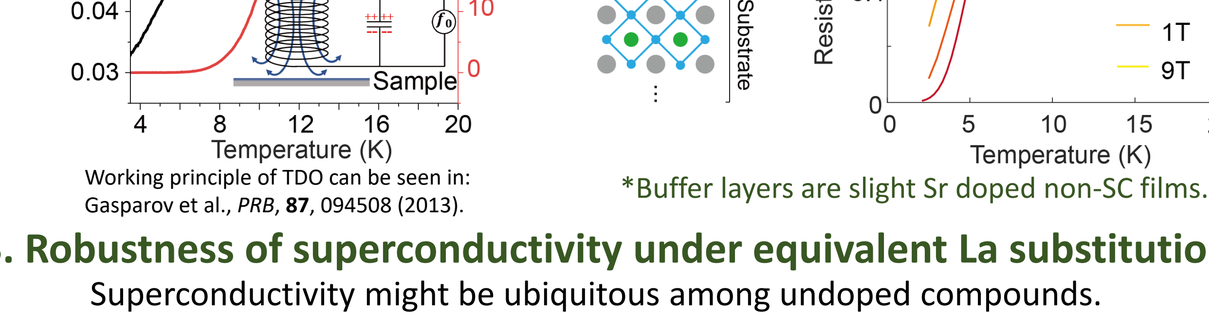
Motivations

- ❖ Why superconductivity in a "parent compound"? Bulk or interfacial origin?
- ❖ New SC phase diagram in "underdoped regime"?
- ❖ The robustness of the SC phase in undoped compounds?
- ❖ Electronic structure of SC samples changed?
- ❖ Can the strong correlation picture of cuprates alone explain this SC phase?

Experimental Results

1. Zero-resistance state in stoichiometric & bare $PrNiO_2$

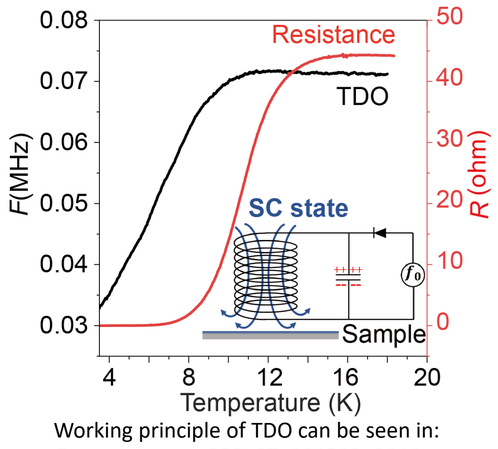
Capping layers are not necessary to achieve this SC phase.



Dashed line: quantum resistivity per NiO_2 plane ρ_q=0.85 mΩ·cm

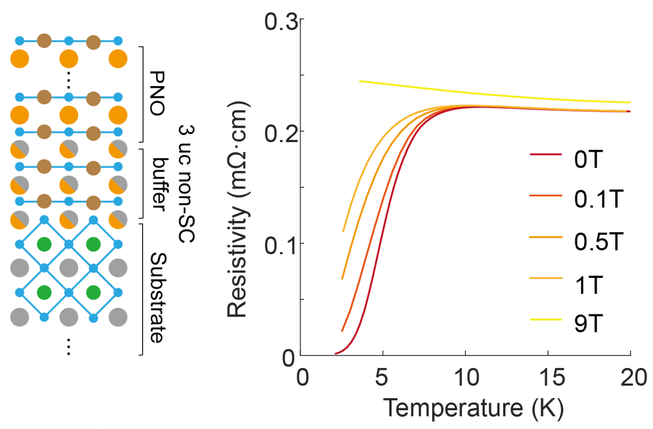
2. Intrinsic bulk superconductivity

2.1 Tunnel diode oscillator (TDO): diamagnetic response



Working principle of TDO can be seen in: Gasparov et al., *PRB*, **87**, 094508 (2013).

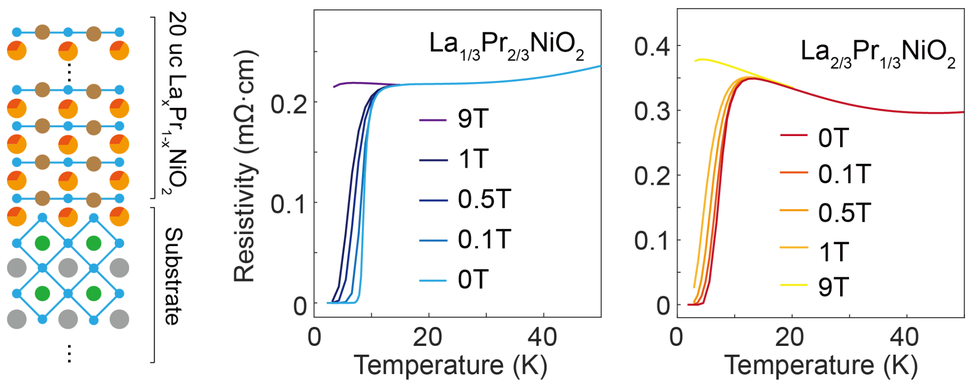
2.2 Superconductivity in $PrNiO_2$/non-SC buffer: disfavor interfacial superconductivity



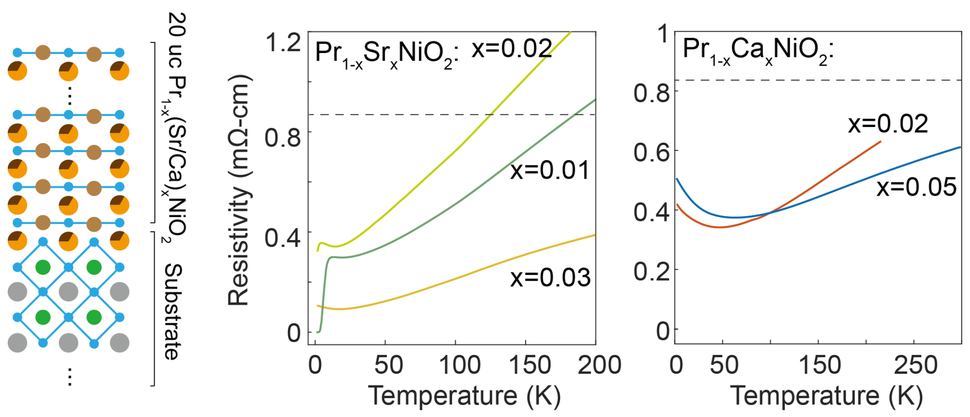
*Buffer layers are slight Sr doped non-SC films.

3. Robustness of superconductivity under equivalent La substitution

Superconductivity might be ubiquitous among undoped compounds.



4. High sensitivity of superconductivity to hole-doping

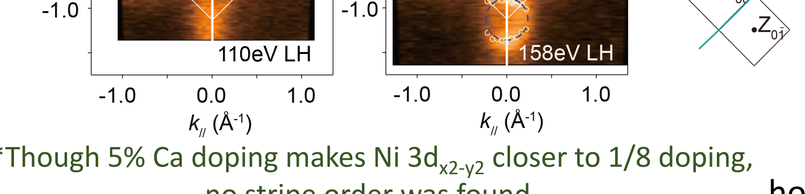


* Slight hole-doping will suppress this phase. Strong-correlation picture can not explain alone.

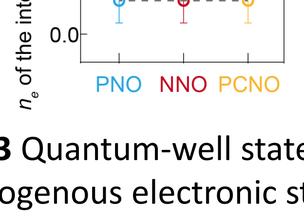
* Can slightly hole-doping act as scattering sites? Such a SC phase requires a very high RRR?

5. Electronic structure of SC $PrNiO_2$ and non-SC $Pr_{0.95}Ca_{0.05}NiO_2$

5.1 Similar electronic structure with non-SC $NdNiO_2$

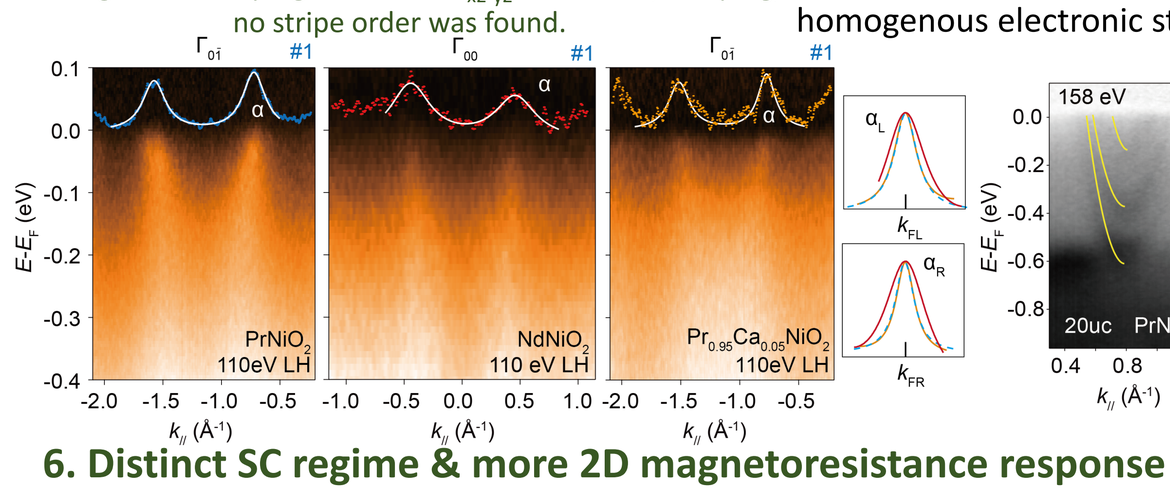


5.2 Self-doping is enough to trigger SC. Ca act as hole carriers



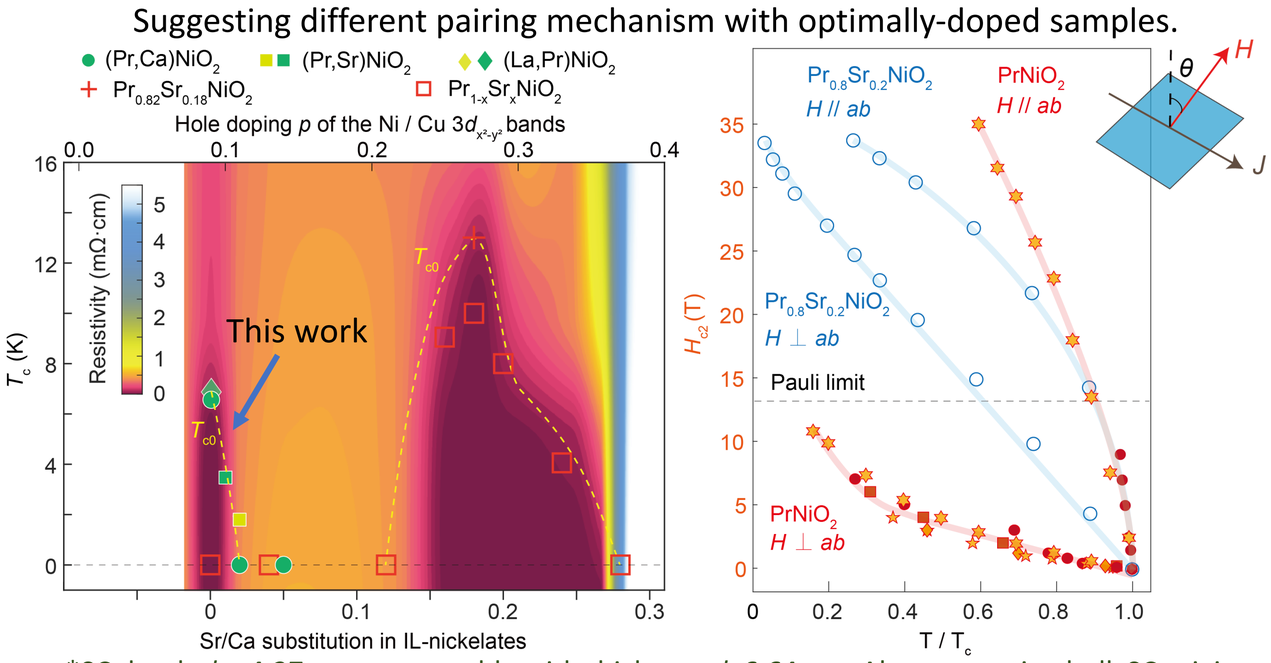
*Though 5% Ca doping makes Ni $3d_{x2-y2}$ closer to 1/8 doping, no stripe order was found.

5.3 Quantum-well states: homogenous electronic states



6. Distinct SC regime & more 2D magnetoresistance response

Suggesting different pairing mechanism with optimally-doped samples.



*SC depth d_{sc}=4.27 nm, comparable with thickness d=6.64 nm. Also supporting bulk SC origin.

*PNO exhibit similar C_2 in-plane symmetry with PSNO. -> similar magnetic environment.

Conclusions & outlook

- ❖ Intrinsic bulk SC was observed in stoichiometric $PrNiO_2$ without capping layers.
- ❖ The electronic structure & doping level in undoped IL-nickelates is sufficient to trigger the superconducting phase.
- ❖ The SC phase is suppressed upon slightly hole doping (disconnected with optimally-doped phase). The strong-correlation picture can not explain alone.
- ❖ Extreme 2D magnetoresistance response + exceed Pauli limit, suggesting a different unconventional SC mechanism with optimally-doped SC phase.

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