The occurrence of superconductivity in proximity to various strongly correlated phases of matter has drawn extensive focus on their normal state properties, to develop an understanding of the state from which superconductivity emerges. The recent finding of superconductivity in layer nickelates raises similar interests. However, transport measurements of doped infinite-layer nickelate thin films have been hampered by materials limitations of these metastable compounds: in particular, a high density of extended defects. Here, by moving to a substrate that better stabilizes the growth and reduction conditions, we can synthesize the doping series of Nd$_1-x$Sr$_x$NiO$_2$ essentially free from extended defects. In their absence, the normal state resistivity shows a low-temperature upturn in the underdoped regime, linear behaviour near optimal doping and quadratic temperature dependence for overdoping. This is phenomenologically similar to the copper oxides, despite key distinctions—namely, the absence of an insulating parent compound, multiband electronic structure and a Mott–Hubbard orbital alignment rather than the charge-transfer insulator of the copper oxides. We further observe an enhancement of superconductivity, both in terms of transition temperature and range of doping. These results indicate a convergence in the electronic properties of both superconducting families as the scale of disorder in the nickelates is reduced.

The idea that superconductivity can arise from doping a correlated insulator has been a pervasive guiding principle since the discovery of the copper oxide superconductors, with an impact on materials as far-ranging as twisted bilayer graphene. On doping the insulator, a ‘strange metal’ with unconventional electrical transport often occurs and nucleates superconductivity, before further doping gives way to more conventional Fermi-liquid-like behaviour. The extent to which this phenomenon requires that the parent compound shows a strongly insulating ground state, and whether or not it should show magnetism has been discussed for decades. A further dichotomy, whether the strange metallic behaviour reflects the proximity to the correlated insulator or follows from a zero-temperature phase transition to a broken symmetry phase, remains actively debated and largely unresolved.

The observation of superconductivity in a family of layered nickelates presents an opportunity to address some of these perplexing issues. The parent compounds of the infinite-layer nickelates show a weak resistive upturn at low temperatures without a strongly insulating ground state or indications of a gap (NdNiO$_2$ and PrNiO$_2$), and even evidence of superconductivity in LaNiO$_2$ (refs. 5,6,9,10). Moreover, so far, long-range magnetic order has not been observed in this system. Nevertheless, upon doping, we find that Nd$_{1-x}$Sr$_x$NiO$_2$ shows strange metal behaviour with resistivity linearly increasing with temperature $T$ for Sr doping $x$ at the peak of the superconducting dome. Further hole doping results in a metallic state with resistivity varying as $T^2$, with reduced and ultimately vanishing superconducting scales. Our results indicate, therefore, that much of the emergent behaviour of this class of unconventional superconductors does not strictly require a Mott insulating parent compound with a hard gap to charge excitations. Features in the Hall effect directly correlate with the evolution of the resistivity and may suggest a broken symmetry associated with Fermi surface reconstruction. Our results can be considered in two contexts: the multiband nature of the electronic structure and the possibility of a quantum phase transition underlying the strange metallic behaviour.

Materials advances
A central issue for the synthesis and study of superconducting infinite-layer nickelates is material control due to the poor thermodynamic stability of this system, as evident from the orders-of-magnitude variations in the resistivity of infinite-layer nickelates reported across the literature. Just as in the development of copper oxides, minimizing disorder and extrinsic defects is critical for elucidating the nature of the normal state and superconducting phase diagram.
We have achieved substantial advances in the crystallinity of Nd$_{1-x}$Sr$_x$NiO$_2$ thin films grown on SrTiO$_3$ substrates to optimize the epitaxial mismatch for both the perovskite precursor and the infinite-layer phases (Extended Data Table 1; see Supplementary Information for an extended comparison of SrTiO$_3$ and SrTiO$_3$). We note that the use of SrTiO$_3$ substrates and the enhancement of the superconducting onset transition temperature $T_c$ was first reported by ref. 24 for Pr$_{0.8}$Sr$_{0.2}$NiO$_2$. As shown in the high-angle annular dark-field (HAADF)–scanning transmission electron microscopy (STEM) cross-sectional images (Fig. 1a,b), the Ruddlesden–Popper-type vertical stacking faults$^{9,11,28}$ (marked by yellow dashed outlines in Fig. 1a) that densely populate films grown on the widely used substrate SrTiO$_3$ ($\alpha = 3.905$ Å) are now essentially eliminated on LSAT, leaving a macroscopically clean thin film with minimal defects (Fig. 1b and Extended Data Figs. 1 and 2). This is also reflected in the substantial decrease in resistivity $\rho$ (Fig. 1c). Note that the in-plane lattice constants of the films are locked to the substrate in both cases (Fig. 1a,b and Extended Data Fig. 2a). X-ray diffraction $\theta$–$2\theta$ symmetric scans show prominent film peaks with out-of-plane lattice constant trends associated with systematic Sr doping (Extended Data Fig. 3a–c). Overall, these data indicate that high crystallinity is uniformly established throughout the probed range of Sr doping (Extended Data Figs. 3 and 4), minimizing extended-defect contributions to electrical transport.

**Superconducting dome**

This optimized sample series on LSAT provides a robust platform to investigate the phase diagram of the infinite-layer nickelates. We first observe that $\rho(20$ K) now maintains a similar range of 0.1–0.3 m$\Omega$ cm across all $x$, notably below the scale of a resistance quantum $R_q$ per NiO$_2$ plane (Fig. 2a; see Extended Data Fig. 5 for all individual $\rho(T)$ curves). This includes the underdoped and overdoped regimes, with $\rho(20$ K) roughly 5–30 times lower than any previously reported (roughly 0.6–9 m$\Omega$ cm)$^{10–11}$. This suggests that the low-temperature normal state scattering rate is comparable across the phase diagram, although multiband effects should be considered.

It is noteworthy that a superconducting dome is still observed for films on SrTiO$_3$, a direct correlation was found between the presence of superconductivity and the magnitude of the normal state resistance with respect to $R_q$ (refs. 6, 9). The fact that the normal state resistance depends substantially on the substrate (LSAT versus SrTiO$_3$), whereas the existence of the superconducting dome does not, suggests that the dome itself is not a result of disorder in doped nickelates. However, at a quantitative level, the superconducting dome in the lower resistance films on LSAT is notably larger, with $T_c$ above 20 K for optimal doping at $x \cong 0.15–0.175$ (Fig. 2b), and with a width $\Delta x \cong 0.2$ that is now very comparable to that of the copper oxides ($\Delta x \cong 0.21$ for La$_{2–x}$Sr$_x$CuO$_4$)$^{12}$ (Extended Data Fig. 6). Further data (field suppression of superconductivity and mutual-inductance measurements) for optimal doping are given in Extended Data Fig. 6. We also note that the experimentally observed range of the superconducting dome here shows good agreement with the theoretical calculations in ref. 29. Both the robustness of the dome and the higher $T_c$ indicate that superconductivity here is probably unconventional and cannot be explained purely by electron–phonon mechanisms$^{10–11}$.

**Normal state phase diagram**

Figure 2b shows the variation of the slope of $\rho(T)$ normalized to the room-temperature value across the phase diagram. Three regimes of behaviour are observed, with representative data shown in Fig. 2e–g: a resistive upturn in the underdoped region characterized by $T_{\text{upturn}}$ (the temperature at which the resistivity minimum occurs $(d\rho/dT = 0)$), $\rho \propto T^2$ in the overdoped region, and a narrow range of $\rho \propto T$ at the peak of the superconducting dome.

The evolution of the resistivity is accompanied by systematic features in the Hall coefficient $R_{xy}$. At high temperatures and low doping $R_{xy}$ is negative, whereas it is positive in the low-temperature limit beyond optimal doping (Fig. 2c; see Extended Data Fig. 8 for all individual $R_{xy}(T)$ curves). The boundary defining the sign change in $R_{xy}$ extrapolates to $T = 0$ at optimal doping. The second clear feature in $R_{xy}$ can be seen in the underdoped region. Here, $R_{xy}$ is negative at all temperatures and shows a pronounced local maximum (Fig. 2d). The temperature at which this maximum occurs decreases as a function of doping and tracks the resistive upturn (dark-blue triangles in Fig. 2b), such that both features extrapolate to vanish under the peak of the superconducting dome.

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**Fig. 1 | Enhanced crystallinity of Nd$_{1-x}$Sr$_x$NiO$_2$ thin films on LSAT.** a, HAADF-STEM cross-sectional image of a Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ thin film grown on SrTiO$_3$, synthesized using conditions in ref. 9. Regions bounded by Ruddlesden–Popper-type stacking faults are outlined in yellow dashed lines. The half-unit-cell thickness expected in the perovskite precursor layer and the approximate unit-cell thickness expected for the stacked nickelate phases are marked by blue and purple dashed lines, respectively. The coherence length of the Nd$_{1-x}$Sr$_x$NiO$_2$ interface is $\cong$0.15–0.175 (Fig. 2b), and with a width $\Delta x \cong 0.2$ that is now very comparable to that of the copper oxides ($\Delta x \cong 0.21$ for La$_{2–x}$Sr$_x$CuO$_4$)$^{12}$ (Extended Data Fig. 6). Further data (field suppression of superconductivity and mutual-inductance measurements) for optimal doping are given in Extended Data Fig. 6. We also note that the experimentally observed range of the superconducting dome here shows good agreement with the theoretical calculations in ref. 29. Both the robustness of the dome and the higher $T_c$ indicate that superconductivity here is probably unconventional and cannot be explained purely by electron–phonon mechanisms$^{10–11}$. The fact that the normal state resistance depends substantially on the substrate (LSAT versus SrTiO$_3$), whereas the existence of the superconducting dome does not, suggests that the dome itself is not a result of disorder in doped nickelates. However, at a quantitative level, the superconducting dome in the lower resistance films on LSAT is notably larger, with $T_c$ above 20 K for optimal doping at $x \cong 0.15–0.175$ (Fig. 2b), and with a width $\Delta x \cong 0.2$ that is now very comparable to that of the copper oxides ($\Delta x \cong 0.21$ for La$_{2–x}$Sr$_x$CuO$_4$)$^{12}$ (Extended Data Fig. 6). Further data (field suppression of superconductivity and mutual-inductance measurements) for optimal doping are given in Extended Data Fig. 6. We also note that the experimentally observed range of the superconducting dome here shows good agreement with the theoretical calculations in ref. 29. Both the robustness of the dome and the higher $T_c$ indicate that superconductivity here is probably unconventional and cannot be explained purely by electron–phonon mechanisms$^{10–11}$. The evolution of the resistivity is accompanied by systematic features in the Hall coefficient $R_{xy}$. At high temperatures and low doping $R_{xy}$ is negative, whereas it is positive in the low-temperature limit beyond optimal doping (Fig. 2c; see Extended Data Fig. 8 for all individual $R_{xy}(T)$ curves). The boundary defining the sign change in $R_{xy}$ extrapolates to $T = 0$ at optimal doping. The second clear feature in $R_{xy}$ can be seen in the underdoped region. Here, $R_{xy}$ is negative at all temperatures and shows a pronounced local maximum (Fig. 2d). The temperature at which this maximum occurs decreases as a function of doping and tracks the resistive upturn (dark-blue triangles in Fig. 2b), such that both features extrapolate to vanish under the peak of the superconducting dome.
In the underdoped region, the low-temperature resistivity has been noted to vary as roughly log(1/T) for films on SrTiO$_3$ (ref. 31). Comparing data for films on LSAT, we see that although the resistivity itself is a factor of around four smaller in the cleaner samples, the LSAT samples uniformly show low ρ(20 K) well below the quantum of resistance per NiO$_2$ plane for all x. Contour plots of the slope of ρ(T) normalized by the slope at room temperature for the films on LSAT. The superconducting dome for the films on SrTiO$_3$ (ref. 9) (grey squares) and here on LSAT (red circles) are also depicted, with the onset transition temperature $T_{\text{onset}}$, defined as the temperature at which the second derivative of ρ(T) becomes negative. The boundary at which $\partial_\rho$ is roughly equal to the room-temperature slope (that is, linear resistivity) is marked by black dotted lines. The temperature dependence of ρ in the underdoped, optimal and overdoped regions are labelled. The dark-blue triangles in the underdoped region mark where $\partial_\rho = 0$ ($T_{\text{onset}}$), and the open circles in the overdoped region mark the temperatures at which the $T^2$ fit deviates (grey arrows in Fig. 4).

Contour plots of the Hall coefficient $R_H(T)$ (e) and the slope of $\rho_T (\partial_\rho R_H)$ (d) across the superconducting dome (purple circles). The green squares in c show where $R_H$ crosses zero, and the blue diamonds in d indicate the temperature at which the local extremum of $\rho_T (T)$ occurs. For b - d, the contours were interpolated from the data using natural neighbour interpolation. In a, b, the error bars are the standard deviation of 3–4 samples. e - g, ρ(T) at representative x characteristic of the underdoped (e), overdoped (f) and optimally doped (g) regions. Dotted curves are for the films grown on SrTiO$_3$ (ref. 9), whereas solid curves are the optimized films grown on LSAT. Black arrows in e and f indicate $T_{\text{onset}}$. For g, ρ(T) of single-crystal La$_{1.6}$Sr$_{0.4}$CuO$_4$ with $T$-linear normal state ρ are also plotted for comparison[36,37]. The dashed lines are linear fits to the normal state ρ, with the slopes of the linear fit indicated at the right in units of 10$^{-4}$ mΩ cm K$^{-3}$.
The functional form of $\rho$ from the low-temperature normal state resistivity (Fig. 4e). We also note that the suppression of resistive upturn shows minimal dependence on epitaxial strain (Extended Data Fig. 9). These observations indicate that the resistive upturn in the overdoped region is driven by disorder physics, unlike in the underdoped region where, as we have discussed, it appears to arise from correlation effects. Suppressing the upturn (or superconductivity) with a 14 T magnetic field reveals metallic Fermi-liquid-like $\rho \propto T^2$ at low temperatures, with the quadratic coefficient $A$ essentially uncorrelated with $T_{\text{upturn}}$ or $x$ (Fig. 4e). In addition, the temperature at which the measured resistivity starts to deviate from the low-temperature $T^2$ fit increases as a function of $x$ (Fig. 4a–d), in a manner analogous to the crossover in the functional form of $\rho$ from $T + T^2$ to $T^2$ in the overdoped region of the copper oxide phase diagram.$^{2,38}$ Furthermore, $\rho_H(T)$ rather resembles that in overdoped La$_{2}$Sr$_3$CuO$_4$ in terms of magnitude, functional form and a sign change around 100 K (ref. 39).

**Discussion**

If strange metallicity is not directly tied to a proximate Mott insulator, a commonly invoked alternative would involve scattering off the soft
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Methods

Film growth
Polycrystalline Nd$_x$Sr$_{1-x}$NiO$_3$ targets ($x = 0.05–0.325$) were prepared by pelletizing mixtures of Nd$_2$O$_3$, SrCO$_3$ and NiO powders, decarbonating at 1,200 °C for 12 h, regrinding and repelletizing and then sintering at 1,350 °C for 12 h (Extended Data Fig. 11)$^{33,34}$. Roughly 15 unit cells of Nd$_x$Sr$_{1-x}$NiO$_3$ epitaxial thin films were grown by pulsed-laser deposition with a KrF excimer laser ($\lambda = 248$ nm) on 5 × 5 mm$^2$ LSAT (001) and SrTiO$_3$ (001) substrates, with the substrate surface prepared ex situ by standard acetone-isopropyl alcohol ultrasonication. The films were synthesized using the conditions specified in Extended Data Table 1. Roughly four unit cells of SrTiO$_3$ (001) were grown in situ as a capping layer$^{10}$.

Reduction process
After cutting into two 2.5 × 5 mm$^2$ pieces, the perovskite samples were vacuum-sealed (below 0.1 mTorr) with roughly 0.1 g of CaH$_2$ powder in a Pyrex glass tube, loosely wrapped with aluminum foil to avoid direct contact with CaH$_2$. The glass tube was first heated at 240–260 °C for 2 h, with a temperature ramp rate of 10 °C min$^{-1}$. Then, X-ray diffraction (XRD) $\theta$–$2\theta$ symmetric scan and $\rho$($T$) measurements were performed ex situ to evaluate the degree of topotactic transition. Thirty-minute reductions at 240–260 °C and ex situ characterizations were incrementally continued until the out-of-plane lattice constant, superconducting transition temperature and residual resistivity ratio saturated, indicating complete reduction. The total reduction time across all samples was roughly 2.5–4 h.

Characterization
XRD $\theta$–$2\theta$ symmetric scans and reciprocal space maps were measured using a monochromated Cu K$_\alpha$ source ($\lambda = 1.5406$ Å). Cross-sectional STEM specimens were prepared by a standard focused ion beam (FIB) lift-out process on a Thermo Scientific Helios G4 UX FIB. HAADF–STEM images of the specimens were acquired on an aberration-corrected Thermo Fisher Scientific Spectra 300 X-CFEG operated at 300 kV with a probe convergence semi-angle of 30 mrad and inner (outer) collection angles of 66 (200) mrad. The measurements of $\rho$($H$, $T$) and Hall effect were conducted in a six-point Hall bar geometry using aluminum wire-bonded contacts. The Hall effect was measured to be linear up to the highest measured magnetic field of 14 T. For two-coil mutual-inductance measurements, a pickup coil of 400 turns and lateral dimensions of roughly 0.5 × 0.5 mm$^2$ and a drive coil of 50 turns and lateral dimensions of roughly 0.25 × 0.25 mm$^2$ were made using 20 μm diameter copper wires. The leakage around the film was calibrated using a 100-nm thick aluminium film with the same lateral dimensions as the nickelate samples (2.5 × 5 mm$^2$)$^{43}$.

Data availability
The data that support the findings of this study are available from the corresponding author upon request.

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Author contributions
K.L. and H.Y.H. conceived the project. K.L. and Y.L. fabricated the polycrystalline targets. K.L. fabricated the perovskite thin films. M.O., Y.L. and W.J.K. performed the soft-chemistry reductions. K.L. conducted XRD characterizations. B.Y.W., T.C.W., Y.L., S.H., M.O. and Y.L. performed the transport measurements. B.H.G. and L.F.K. conducted STEM measurements. K.L., B.Y.W., C.M., S.R. and H.Y.H. wrote the manuscript with input from all authors.

Competing interests
The authors declare no competing interests.

Additional information
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Extended Data Fig. 1 | Analytical mapping of Ruddlesden–Popper faults.

a, Raw HAADF-STEM image of the Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ film on SrTiO$_3$ substrate shown in Fig. 1a (left) and a magnified view of the region marked by the red dashed box (right). For the magnified view, atomic overlays are shown to illustrate the half-unit-cell displacement induced by the Ruddlesden–Popper-type stacking faults (RP faults), resulting in the reduced cation contrast. b, Composite of the compressive strain measured on the [101] and [101] pseudocubic lattice fringes for the HAADF-STEM image in a. The infinite-layer film appears as a region of large compressive strain compared to the substrate because of the shortened c-axis lattice constant. Ruddlesden–Popper type faults in the film are highlighted as regions of local expansion (bright lines) within the film. The highlighted boundaries are used to annotate the vertical Ruddlesden–Popper regions, shown as black (yellow) boxes here (in Fig. 1a). c, Identical strain mapping of the [101] and [011] pseudocubic lattice fringes for the HAADF-STEM image of the Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ film on LSAT substrate (Fig. 1b). The circles in b and c illustrate the coarsening length scale of the Fourier-based analysis. Scale bars, 5 nm.
Extended Data Fig. 2 | High-resolution HAADF- and ABF-STEM imaging of Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ film on LSAT. a, High-resolution HAADF- (left) and annular bright-field (ABF)- (right) STEM images of the Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ film on LSAT shown in Fig. 1b. Both the lattice size and oxygen column structure visible in the ABF image are consistent with the infinite-layer structure. Atomic model overlays show columns of Nd/Sr (orange), Ni (purple), La/Sr (green), Al/Ta (blue), and O (red). b, HAADF-STEM image of the same Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ film on LSAT. c, Quantitative tracking of the local c-axis lattice constant measured between consecutive A-site planes (e.g., Nd to Nd). The lattice constant within the film shows good agreement with the expected value for the infinite-layer structure and the measurements of a fully reduced film by XRD. Scale bars, 5 Å.
Extended Data Fig. 3 | X-Ray diffraction of Nd$_{1-x}$Sr$_x$NiO$_2$ on LSAT substrates. 

a, Representative XRD θ–2θ symmetric scans of optimized Nd$_{1-x}$Sr$_x$NiO$_2$ ($x = 0.05–0.325$). The curves are vertically offset for clarity. 

b, XRD θ–2θ symmetric scan of Nd$_{0.85}$Sr$_{0.15}$NiO$_2$ (solid curve) and the corresponding symmetric scan fit (dashed curve). The close agreement in the positions of the main film peak and the Laue fringes indicates a good fit. The asymmetry in the Laue fringes of the film peaks arises from the asymmetric background intensity and the resolution limit of the instrument. The extracted out-of-plane lattice constant $c$ from the fit is labelled.

c, c-axis lattice constant versus $x$ for Nd$_{1-x}$Sr$_x$NiO$_2$ films on LSAT (green filled triangles, extracted from a) and on SrTiO$_3$ (red filled circles) using the same growth conditions (Extended Data Table 1). Error bars are the larger of the error in the fit and standard deviation in the values from multiple samples. $c$ increases linearly with $x$, consistent with systematic doping of Sr in the films. Previous experimental data$^{9,10}$ on SrTiO$_3$ are also shown as open circles. The substantial elimination of Ruddlesden–Popper-type faults, which locally expand the in-plane lattice$^1$, results in the overall decrease in $c$ compared to previous experimental data. In their absence, the larger c-axis lattice constant in LSAT with respect to SrTiO$_3$ is due to larger compressive strain. Dotted lines are linear fits to the experimental data.

d–g, Reciprocal space maps of Nd$_{1-x}$Sr$_x$NiO$_2$ films on LSAT for $x = 0.075$ (d), $x = 0.15$ (e), $x = 0.225$ (f), and $x = 0.3$ (g), showing that the films are fully strained to the LSAT substrate across doping.
Extended Data Fig. 4 | Atomic-scale structural characterization by HAADF-STEM of the Nd_{0.7}Sr_{0.3}NiO_{2} film on LSAT with SrTiO_{3} capping layer.

HAADF-STEM image of the Nd_{0.7}Sr_{0.3}NiO_{2} film on LSAT. Scale bar, 5 nm.
Extended Data Fig. 5 | Individual resistivity curves of Nd$_x$Sr$_{1-x}$NiO$_2$ on LSAT. $\rho$ versus $T$ curves of optimized Nd$_x$Sr$_{1-x}$NiO$_2$ films ($x = 0.05$–$0.325$). Curves for additional samples at $x = 0.075$, $0.15$, and $0.275$ are also shown.
Extended Data Fig. 6 | Comparing the Nd$_{1-x}$Sr$_x$NiO$_2$ and the La$_{2-x}$Sr$_x$CuO$_4$ phase diagrams. Superconducting phase diagram of Nd$_{1-x}$Sr$_x$NiO$_2$ on LSAT (red) and La$_{2-x}$Sr$_x$CuO$_4$ (green), both plotted against the nominal Sr composition $x$. The superconducting onset temperature is shown via circles, while the resistive upturn temperature $T_{\text{upturn}}$ is shown as triangles. For La$_{2-x}$Sr$_x$CuO$_4$, the open triangles are $T_{\text{upturn}}$ obtained by suppressing superconductivity with high magnetic field. The superconducting dome extends from $x \approx 0.1$–0.3 ($\Delta x = 0.2$) for Nd$_{1-x}$Sr$_x$NiO$_2$ and $x = 0.05$–0.26 ($\Delta x = 0.21$) for La$_{2-x}$Sr$_x$CuO$_4$. 
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Extended Data Fig. 7 | Suppression of superconductivity by magnetic field.

a, ρ versus T of Nd$_{0.825}$Sr$_{0.175}$NiO$_2$ film on LSAT under perpendicular magnetic field (0.2–14 T, indicated by color). b, The real (red, left) and imaginary (blue, right) parts of the inductance $L_p$ as a function of T in the pickup coil on a Nd$_{0.825}$Sr$_{0.175}$NiO$_2$ film on LSAT, measured using a two-coil mutual-inductance measurement (see Methods).
Extended Data Fig. 8 | Individual $R_H(T)$ curves of Nd$_{1-x}$Sr$_x$NiO$_2$ on LSAT. $R_H$ versus $T$ curves of optimized Nd$_{1-x}$Sr$_x$NiO$_2$ films ($x = 0.05$–$0.325$) on LSAT substrate. $R_H = 0$ is marked as a black dotted line.
Extended Data Fig. 9 | Minimal epitaxial strain dependence of $T_{\text{upturn}}$ of $\rho(T)$ of Nd$_{x}$Sr$_{1-x}$NiO$_{2}$ films on SrTiO$_{3}$ (blue) and LSAT (red), both synthesized using the growth parameters specified in Extended Data Table 1. Prior data of $\rho(T)$ of Nd$_{0.75}$Sr$_{0.25}$NiO$_{2}$ film on SrTiO$_{3}$ from ref. 9 (yellow dashed curve, see Fig. 2f) is also plotted for comparison. The films on SrTiO$_{3}$ show considerable suppression of $T_{\text{upturn}}$ (black arrows) upon enhanced crystallinity, with similar order of suppression as the film on LSAT. This suggests that the suppression of the resistive upturn is primarily due to higher film quality, and epitaxial strain plays a sub-dominant role in the resistive upturn.
Extended Data Fig. 10 | Cumulative phase diagram of the infinite-layer nickelate Nd$_{1-x}$Sr$_x$NiO$_2$ on LSAT. The main features of the phase diagram of Nd$_{1-x}$Sr$_x$NiO$_2$ are summarized here. The onset temperature of the superconducting transition $T_{c,\text{onset}}$ is defined as the temperature at which the second derivative of $\rho(T)$ becomes negative, and the 50% transition temperature $T_{c,50\%}$ is defined as the temperature at which $\rho$ is 50% of $\rho(T_{c,\text{onset}})$. In the underdoped region, $\rho$ shows a resistive upturn, with $T_{c,\text{onset}}$ (dark-blue triangles) decreasing as hole doping is increased and superconductivity emerges. Simultaneously, the local maximum in $R_H$ (light-blue diamonds) tracks the doping dependence of the resistive $T_{c,\text{onset}}$. Superconductivity emerges at $x \approx 0.1$ and persists up to $x \approx 0.3$.

In the optimal doping of $x \approx 0.15$–0.175, the normal-state resistivity shows a linear $T$-dependence. As superconductivity is suppressed in the overdoped region, $T^2$ resistivity emerges, with a small resistive upturn at low temperatures (dark-blue triangles) driven by disorder. The open circles at the overdoped region delineate the boundary below which the $T^2$ fit shows good agreement with $\rho$. As $x$ is increased, $R_H$ starts to cross zero into positive values (green squares). This transition occurs near the optimal doping, and the zero-crossing temperature increases into the overdoped region.
Extended Data Fig. 11 | Powder XRD of polycrystalline target. Powder XRD of polycrystalline nickelate target with nominal stoichiometry of Nd$_{0.825}$Sr$_{0.175}$Ni$_{1.15}$O$_3$ (red), along with bulk powder XRD of Nd$_2$NiO$_4$ and NiO$^{44,45}$. Aside from minor shifts in the peak positions due to chemical substitution of Sr, the observed peaks of the target are a superposition of Nd$_2$NiO$_4$ and NiO$^2$. 
Extended Data Table 1 | Pulsed-laser deposition growth parameters optimized for perovskite Nd$_{1-x}$Sr$_x$NiO$_3$ thin films on LSAT

| Growth Parameters                  | Parameter Values |
|-----------------------------------|------------------|
| Fluence (J cm$^{-2}$)             | 2.6              |
| Laser spot size (mm$^2$)          | 0.77             |
| Target composition                | 15% Ni rich      |
| Pre-ablation pulse number         | 241              |
| Target track outer diameter (cm)  | 1.0–1.1          |
| Substrate-to-Target Distance (mm) | 55.5             |
| $P_{O_2}$, deposition (mTorr)     | 150              |
| $T$, deposition (°C)              | 580              |

The optimized infinite-layer films were obtained across $x$ by reducing the perovskite films at 240–260 °C for roughly 2.5–4 h (see Methods). We note that under the same reduction conditions, complete reduction could not be achieved for $x < 0.05$ on LSAT, and thus we limit our study to $x = 0.05$–0.325 (see Supplementary Information). For growth on SrTiO$_3$, the substrate was pre-annealed at 900 °C for 30 min at oxygen partial pressure $P_{O_2} = 5 \times 10^{-6}$ Torr.
Extended Data Table 2 | Summary of superconducting transition temperatures of Nd$_{1-x}$Sr$_x$NiO$_2$ thin films on LSAT

| $x$   | $T_{c,\text{onset}}$ (K) | $T_{c,90\%}$ (K) | $T_{c,50\%}$ (K) | $T_{c,10\%}$ (K) | $T_{c,\text{0}}$ (K) |
|-------|--------------------------|------------------|------------------|------------------|------------------|
| 0.125 | 20.1 ± 0.1               | 14.5 ± 0.6       | 12.4 ± 0.7       | 10.8 ± 0.7       | 6.9 ± 0.7        |
| 0.15  | 23.0 ± 0.1               | 19.2 ± 0.1       | 17.6 ± 0.1       | 16.5 ± 0.2       | 14.3 ± 0.2       |
| 0.175 | 23.0 ± 0.5               | 19.2 ± 0.1       | 17.5 ± 0.1       | 16.4 ± 0.2       | 14.1 ± 0.2       |
| 0.1875| 19.7 ± 0.3               | 15.1 ± 0.3       | 13.3 ± 0.1       | 11.9 ± 0.1       | 8.5 ± 0.3        |
| 0.2   | 19.3 ± 0.1               | 15.7 ± 0.1       | 13.9 ± 0.1       | 12.8 ± 0.2       | 10.5 ± 0.3       |
| 0.2125| 17.5 ± 0.7               | 14.2 ± 0.6       | 12.6 ± 0.6       | 11.5 ± 0.5       | 9.6 ± 0.6        |
| 0.225 | 16.0 ± 0.3               | 11.9 ± 0.1       | 9.8 ± 0.2        | 8.5 ± 0.2        | 6.2 ± 0.3        |
| 0.25  | 14.3 ± 0.5               | 10.5 ± 0.5       | 8.6 ± 0.4        | 7.2 ± 0.5        | 4.8 ± 0.2        |
| 0.275 | 7.7 ± 0.3                | 5.1 ± 0.3        | 4.0 ± 0.2        | 3.0 ± 0.2        | < 2             |

The onset temperature of the superconducting transition $T_{c,\text{onset}}$ is defined as the temperature at which the second derivative of $\rho(T)$ becomes negative. The 90%, 50%, and 10% transition temperatures ($T_{c,90\%}$, $T_{c,50\%}$, and $T_{c,10\%}$, respectively) are defined as the temperatures at which $\rho$ is 90%, 50%, and 10% of $\rho(T_{c,\text{onset}})$, respectively. $T_{c,\text{0}}$ is the temperature at which $\rho=0$. 