The “pseudogap” phase of the high temperature superconductors

ITAMP, Harvard
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High temperature superconductors

\[ \text{YBa}_2\text{Cu}_3\text{O}_{6+x} \]
High temperature superconductors

$YBa_2Cu_3O_{6+x}$

$CuO_2$ plane
The absence of any intensity loss at low temperatures also rules out the presence of magnetic order with any significant moment. Error bars represent the added uncertainty in defining the onset of the NMR line splitting (Fig. 1f). The field therefore affects relaxation rate $1/\tau_e$.

<table>
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<th>$T$ (K)</th>
<th>$p$ (hole/Cu)</th>
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<tr>
<td>0</td>
<td>0.04</td>
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<td>40</td>
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<td>80</td>
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In stripe-ordered copper oxides, the strong increase of $1/\tau_e$ below which slow spin fluctuations cause $1/\tau_e$ represents the uncertainty in defining the onset of the Fermi surface changes its sign.

In principle, such slow fluctuations could reconstruct the Fermi surface, provided that spins are correlated over large enough distances face, provided that spins are correlated over large enough distances. The charge differentiation is more likely to be a consequence of stripe order (the smectic phase of an electronic liquid crystal) and for the extrapolation of the field-induced charge order. The magnetic transition temperature depends on $T_p$, stretching exponent $\alpha$, and to become field dependent; note that the change of shape of the spin-echo decay to a stretched form.

The extrapolation of the field-induced charge order. The magnetic transition temperature does not imply that antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to temperature $T_c$.

A scenario of $v_p$. A similar field-induced spin order has been predicted for $\approx 33.5$ T, whereas no line splitting is detected at this field. The field therefore affects the spin polarization as small as $\approx 15$ T, temperature, and for the central lines at base temperature sets an upper magnitude for the static information) indicates that the spins, although staggered, align mostly parallel to the $c$ axis. Superconducting Information) indicates that the spins, although staggered, align mostly parallel to the $c$ axis, and to become field dependent; note that the change of shape of the spin-echo decay actually becomes a combination of exponential and Gaussian.

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The extrapolation of the field-induced charge order. The magnetic transition temperature sharply increases below $T_p$.

$T_p$ is always accompanied by spin order at $T_p$, whereas no line splitting is detected at this field. The field therefore affects $1/\tau_e$; changes its sign.

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panied by spin order at temperatures probably signifies that the condition consequence of charge-stripe order. The increase of relaxation rate $1/T$ intensity (corrected for a temperature factor $1/T$) the spin fluctuations quantitatively but not qualitatively. All measurements are with $T_g$ Gaussian and exponential decays, combined with some spatial distribution of deviation from $p$. The absence of any peak/enhancement on cooling rules 2 on cooling arises mostly from an intrinsic combination of 2 slow fluctuations being a defining property of the ordered state, the small amplitude of temperature range in $YBa_{2}Cu_{3}O_{7}$. $Cu(2)$ signal here in $T_{c}$, for which the non-magnetic ground state switches to magnetic (or 'spin-density-wave') fluctuations are slow enough to vanish close to the same critical concentration. Our work, however, shows that spin order does not occur up to $30 T$. A similar field-dependent charge order actually underlies the field-induced spin order has been predicted for $La_{2-x}Sr_{x}CuO_{4}$, for which the non-magnetic ground state switches to magnetic (or ‘spin-density-wave’) fluctuations are slow enough to vanish close to the same critical concentration.

Figure 4

The spin fluctuations quantitatively but not qualitatively.

15 T, whereas no line splitting is detected at this field. The field therefore affects echo decay to a stretched form of being a defining property of the ordered state, the small amplitude of slow spin fluctuations instead of spin order. a

$$a \propto 0.12 \quad (\text{K})$$

The absence of any peak/enhancement on cooling rules the presence of free-electron-like Zeeman splitting (K) charge order. For which the non-magnetic ground state switches to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to transition temperature $T_c$ | Cu. Therefore, instead of magnetic (or 'spin-density-wave') fluctuations are slow enough to vanish close to the same critical concentration $x = 0.108 \quad (\text{K})$. The continuous line represents the superconducting crossover occurs here, albeit in a less extreme manner because of the anisotropy of the linewidth (Supplementary Figs 8–10).

In principle, such slow fluctuations could reconstruct the Fermi surface reconstruction $\mathbf{T}$. Moreover, the anisotropy of the linewidth (Supplementary Information) data (green stars) represent the uncertainty in defining the onset of the NMR line splitting (Fig. 1f). In Supplementary Information we provide evidence for the presence of free-electron-like Zeeman splitting and Supplementary Figs 8–10).

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Superconductivity:
Bose condensation of Cooper pairs of electrons

\[ \varepsilon^{\alpha\beta} \left\langle c^\dagger_{\alpha}(\mathbf{r}_1)c^\dagger_{\beta}(\mathbf{r}_2) \right\rangle = \left[ P(\mathbf{r}_1 - \mathbf{r}_2) \right] \times \Psi_{SC} \left( \frac{\mathbf{r}_1 + \mathbf{r}_2}{2} \right) \]

\( \alpha, \beta = \uparrow, \downarrow \); \( \varepsilon^{\uparrow\downarrow} = -\varepsilon^{\downarrow\uparrow} = 1 \); \( \varepsilon^{\uparrow\uparrow} = \varepsilon^{\downarrow\downarrow} = 0 \)
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Nearly constant condensate wavefunction (superconducting order parameter)

\[ \alpha, \beta = \uparrow, \downarrow \quad ; \quad \varepsilon^{\uparrow\downarrow} = -\varepsilon^{\downarrow\uparrow} = 1 ; \quad \varepsilon^{\uparrow\uparrow} = \varepsilon^{\downarrow\downarrow} = 0 \]
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Internal Cooper-pair wavefunction. Has \( d \)-wave form in cuprates

\[ \alpha, \beta = \uparrow, \downarrow \quad ; \quad \varepsilon^{\uparrow\downarrow} = -\varepsilon^{\downarrow\uparrow} = 1 \quad ; \quad \varepsilon^{\uparrow\uparrow} = \varepsilon^{\downarrow\downarrow} = 0 \]
Phase-sensitive measurement of the \textit{d}-wave symmetry of Cooper pairs

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**Pairing Symmetry and Flux Quantization in a Tricrystal Superconducting Ring of YBa$_2$Cu$_3$O$_{7-\delta}$**


\textit{IBM Thomas J. Watson Research Center, P.O. Box 218, Yorktown Heights, New York 10598}

Phys. Rev. Lett. 73, 593 (1994)
In stripe-ordered copper oxides, the strong increase of $1/T$ below which slow spin fluctuations cause $1/T$ decay actually becomes a combination of exponential and Gaussian decay to a stretched form. We note that the upturn of $1/T$ is no longer fulfilled, so that the associated decay is no longer a pure exponential. Moreover, the anisotropy of the linewidth (Supplementary Information) indicates that the spins, although staggered, align mostly along the field (that is, nematic). The absence of any peak/enhancement on cooling rules out magnetic order, in agreement with an earlier suggestion based on the magnetic (or 'spin-density-wave') fluctuations are slow enough to vanish close to the same critical concentration. In stripe-ordered copper oxides, the strong increase of $1/T$ on cooling arises mostly from an intrinsic combination of magnetic and charge-field induced order. The increase of temperature probably signifies that the condition consequence of charge-stripe order. The increase of temperature below which slow spin fluctuations cause $1/T$ decay occurs at a slightly higher ($T = 28.5 \text{T}$) and to become field dependent; note that the change of shape of the spin-echo echo decay to a stretched form.

The absence of any peak/enhancement on cooling rules out magnetic order: $1/T$ changes its sign. The correlation time, is no longer fulfilled, so that the associated decay is no longer a pure exponential. We note that the upturn of $1/T$ is no longer fulfilled, so that the associated decay is no longer a pure exponential.
Ordinary metal (Fermi liquid) at large hole density

“Fermi arcs” at low doping

X-ray scattering

In stripe-ordered copper oxides, the strong increase of $1/T_1$ below which slow spin fluctuations cause $1/T_1$ to become a combination of exponential and Gaussian is always accompanied by a spin-echo decay to a stretched form. A scenario of slow spin fluctuations instead of spin order. The increase of the spin-echo from the high-temperature Gaussian form actually becomes a combination of exponential and Gaussian. A similar decay occurs at a slightly higher ($\approx$15 K) temperature than $T_c$ for the extrapolation of the field-induced charge order. The magnetic transition sharply increases below $T_g$ so large that the Cu signal is gradually ‘wiped out’ on cooling below $T_g$ below which slow spin fluctuations cause $1/T_1$ to become a combination of exponential and Gaussian, which is consistent with the slow fluctuations being a consequence of charge-stripe order. The increase of the planar Cu spin–lattice relaxation rate $1/T_2$ dependence of the charge frustrated Cu spin–spin correlation time, is no longer fulfilled, so that the associated decay is no longer a pure exponential. We note that the upturn of $1/T_2$ is always accompanied by spin order at low temperatures also rules out the presence of free-electron-like Zeeman splitting magnetic order, in agreement with an earlier suggestion based on the central lines at base temperature sets an upper magnitude for the static scattering.

In stripe-ordered cuprate systems, the relaxation rates become strongly hyperfine-coupled for the more strongly hyperfine-coupled $^{63}$Cu nuclei. For $^{63}$Cu, the relaxation rates become four times faster than for $^{63}$Y, for which the non-magnetic ground state switches to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references 11–13). The magnetic transition sharply increases below $T_g$ so large that the Cu signal is gradually ‘wiped out’ on cooling below $T_g$ below which slow spin fluctuations cause $1/T_1$ to become a combination of exponential and Gaussian, which is consistent with the slow fluctuations being a consequence of charge-stripe order. The increase of the planar Cu spin–lattice relaxation rate $1/T_2$ dependence of the charge frustrated Cu spin–spin correlation time, is no longer fulfilled, so that the associated decay is no longer a pure exponential. We note that the upturn of $1/T_2$ is always accompanied by spin order at low temperatures also rules out the presence of free-electron-like Zeeman splitting magnetic order, in agreement with an earlier suggestion based on the central lines at base temperature sets an upper magnitude for the static scattering.

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Direct observation of competition between superconductivity and charge density wave order in YBa$_2$Cu$_3$O$_{6.67}$

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**Graphs and Diagrams**

- **Graph A**: Intensity versus temperature for different magnetic fields.
- **Graph B**: Phase diagram showing temperature versus doping concentration with various phase transitions labeled.
- **Diagrams A, B, C**: Comparative intensity scans at different temperatures and fields for different cuts.

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**References**


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**Abstract**

This study investigates the interplay between superconductivity and charge density wave (CDW) order in the high-temperature superconductor YBa$_2$Cu$_3$O$_{6.67}$. By combining experimental techniques such as resonant soft X-ray scattering and quantum oscillation experiments, researchers have observed the coexistence of these two orders as a function of temperature and magnetic field. Key findings include the modulation of vortex cores in antiphase and the observation of charge scatter by counting statistics, which contribute to a more long-range ordered CDW as the field is applied. This work provides strong evidence for the competition with symmetry-breaking ground states such as superconductivity and charge density wave, thus illustrating a broken rotational symmetry inside the pseudogap phase. The study further reveals the temperature dependence of the lattice modulation peak intensity at $(1.695, 0, 0.5)$ for different fields, with a focus on the magnetic field dependence of the lattice modulation peak intensity at $(0, 3.691, 0.5)$ (x4), demonstrating the field-induced signal and its enhancement of CDW correlations in this high-temperature superconductor.
Comparison of Monte Carlo with experiments

\[ S_{\Phi_x} = \int d^2r \langle \Phi_x(r)\Phi_x(0) \rangle \]

Charge order structure factor \( S_{\Phi_x} \)

For \( ga^2 = 0.30 \) and \( wa^2 = 0.0 \) we have \( \rho_s = 160K \).
The height was also rescaled to make the peak heights match.

Comparison of Monte Carlo with experiments

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Comparison of Monte Carlo with experiments

For \( ga^2 = 0.30 \) and \( wa^2 = 0.0 \) we have \( \rho_s = 160 \text{K} \). The height was also rescaled to make the peak heights match.

In stripe copper oxides, charge order at values (Supplementary Information). The grey areas define the crossover evidence (explaining the rotational symmetry breaking) over a broad range. The absence of any peak/enhancement on cooling rules out the occurrence of a magnetic transition. Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein). Our work, however, shows that spin order does not occur up to antiferromagnetic order in fields greater than a few teslas (ref. 7 and references therein).
A Four Unit Cell Periodic Pattern of Quasi-Particle States Surrounding Vortex Cores in Bi$_2$Sr$_2$CaCu$_2$O$_{8+\delta}$

A Four Unit Cell Periodic Pattern of Quasi-Particle States Surrounding Vortex Cores in Bi$_2$Sr$_2$CaCu$_2$O$_{8+\delta}$


A charge density wave (CDW) with wavelength $\approx 4$ lattice spacings around vortex cores?


A density wave with wavelength $\approx 4$ lattice sites?
See also


Charge density wave (CDW) order

\[ \langle c^\dagger_{\alpha}(r)c_{\alpha}(r) \rangle = \Psi_{CDW}(r) e^{iQ \cdot r} + \text{c.c.} \]
Charge density wave (CDW) order

\[ \langle c_{\alpha}^\dagger (\mathbf{r}) c_{\alpha} (\mathbf{r}) \rangle = \Psi_{CDW} (\mathbf{r}) e^{iQ \cdot \mathbf{r}} + \text{c.c.} \]

Nearly constant CDW order parameter
Plot of $P_{ii} = \langle c_{i\alpha}^{\dagger} c_{i\alpha} \rangle$ with

$$P_{ii} = e^{iQ \cdot r_i} + \text{c.c.}$$

with $Q = 2\pi(1/4, 0)$
**Unconventional** density wave (DW): Bose condensation of particle-hole pairs

\[
\langle c_\alpha^\dagger(r_1) c_\alpha(r_2) \rangle = \left[ \mathcal{P}(r_1 - r_2) \right] \times \Psi_{DW} \left( \frac{r_1 + r_2}{2} \right) e^{i \mathbf{Q} \cdot (r_1 + r_2)/2} + \text{c.c.}
\]
**Unconventional** density wave (DW): Bose condensation of particle-hole pairs

\[
\langle c_{\alpha}^\dagger (\mathbf{r}_1) c_{\alpha} (\mathbf{r}_2) \rangle \\
= \left[ \mathcal{P}(\mathbf{r}_1 - \mathbf{r}_2) \right] \times \Psi_{DW} \left( \frac{\mathbf{r}_1 + \mathbf{r}_2}{2} \right) e^{i \mathbf{Q} \cdot (\mathbf{r}_1 + \mathbf{r}_2)/2} + \text{c.c.}
\]

Crucial “center-of-mass” co-ordinate.
(Not used in previous work)
Simplifies action of time-reversal
Unconventional density wave (DW) : Bose condensation of particle-hole pairs

\[
\langle c_\alpha^\dagger(r_1)c_\alpha(r_2) \rangle = \left[ \mathcal{P}(r_1 - r_2) \right] \times \Psi_{DW} \left( \frac{r_1 + r_2}{2} \right) e^{iQ \cdot \frac{(r_1 + r_2)}{2}} + \text{c.c.}
\]

Nearly constant CDW order parameter
**Unconventional** density wave (DW): Bose condensation of particle-hole pairs

\[
\langle c_\alpha^\dagger(\mathbf{r}_1)c_\alpha(\mathbf{r}_2) \rangle = \left[ \mathcal{P}(\mathbf{r}_1 - \mathbf{r}_2) \right] \times \Psi_{DW} \left( \frac{\mathbf{r}_1 + \mathbf{r}_2}{2} \right) e^{i\mathbf{Q} \cdot (\mathbf{r}_1 + \mathbf{r}_2)/2} + \text{c.c.}
\]

Density wave **form factor** (internal particle-hole pair wavefunction)

\[
\mathcal{P}(\mathbf{r}) = \int \frac{d^2k}{4\pi^2} \mathcal{P}(\mathbf{k}) e^{i\mathbf{k} \cdot \mathbf{r}}
\]

Time-reversal symmetry requires \( \mathcal{P}(\mathbf{k}) = \mathcal{P}(-\mathbf{k}) \).

We expand (using reflection symmetry for \( \mathbf{Q} \) along axes or diagonals)

\[
\mathcal{P}(\mathbf{k}) = \mathcal{P}_s + \mathcal{P}_{s'}(\cos k_x + \cos k_y) + \mathcal{P}_d(\cos k_x - \cos k_y)
\]
Conventional CDW order: $s$-form factor

Plot of $P_{ij} = \langle c_{i\alpha}^{\dagger} c_{j\alpha} \rangle$ for $i = j$, and $i, j$ nearest neighbors.

$$P_{ij} = \left[ \int \mathcal{P}(\mathbf{k}) e^{i\mathbf{k} \cdot (\mathbf{r}_i - \mathbf{r}_j)} \right] e^{i\mathbf{Q} \cdot (\mathbf{r}_i + \mathbf{r}_j) / 2} + \text{c.c.}$$

$$\mathcal{P}(\mathbf{k}) = 1 \quad \text{and} \quad \mathbf{Q} = 2\pi (1/4, 0)$$
Unconventional DW order: $s'$-form factor

Plot of $P_{ij} = \langle c^\dagger_{i\alpha} c_{j\alpha} \rangle$ for $i = j$, and $i, j$ nearest neighbors.

$$P_{ij} = \left[ \int_{\mathbf{k}} \mathcal{P}(\mathbf{k}) e^{i\mathbf{k} \cdot (\mathbf{r}_i - \mathbf{r}_j)} \right] e^{i \mathbf{Q} \cdot (\mathbf{r}_i + \mathbf{r}_j)/2} + \text{c.c.}$$

$$\mathcal{P}(\mathbf{k}) = e^{i\phi} [\cos(k_x) + \cos(k_y)] \quad \text{and} \quad \mathbf{Q} = 2\pi (1/4, 0)$$
Unconventional DW order: $s'$-form factor

Compatible with “stripe” model, and spin-density-wave (SDW) order

$s'$-CDW

$s'$-CDW + SDW

Orbital symmetry of charge density wave order in La$_{1.88}$Ba$_{0.12}$CuO$_4$ and YBa$_2$Cu$_3$O$_{6.67}$

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X-ray observations indicate strong $s'$ component in LBCO
The $s'$-form factor density wave order is incompatible with STM measurements on BSCCO, Na-CCOC.
Unconventional DW order: $s'$-form factor

Plot of $P_{ij} = \langle c^\dagger_{i\alpha} c_{j\alpha} \rangle$ for $i = j$, and $i, j$ nearest neighbors.

$$P_{ij} = \left[ \int \mathcal{P}(k) e^{i k \cdot (r_i - r_j)} \right] e^{i Q \cdot (r_i + r_j)/2} + \text{c.c.}$$

$$\mathcal{P}(k) = e^{i \phi} [\cos(k_x) + \cos(k_y)] \quad \text{and} \quad Q = 2\pi (1/4, 0)$$
Unconventional DW order: \( d \)-form factor

Plot of \( P_{ij} = \langle c_{i\alpha}^\dagger c_{j\alpha} \rangle \) for \( i = j \), and \( i, j \) nearest neighbors.

\[
P_{ij} = \left[ \int_k \mathcal{P}(k) e^{ik \cdot (r_i - r_j)} \right] e^{iQ \cdot (r_i + r_j)/2} + \text{c.c.}
\]

\[
\mathcal{P}(k) = e^{i\phi} [\cos(k_x) - \cos(k_y)] \quad \text{and} \quad Q = 2\pi(1/4, 0)
\]

Density wave on horizontal bonds has a phase-shift of \( \pi \) relative to the wave on vertical bonds.

This specific \( d \)-form factor density wave order (with \( Q \) along the axes) was first predicted in S. Sachdev and R. LaPlaca, Phys. Rev. Lett. 111, 027202 (2013).
This specific $d$-form factor density wave order (with $Q$ along the axes) was first predicted in S. Sachdev and R. LaPlaca, Phys. Rev. Lett. 111, 027202 (2013).
$Q = (\pi/2, 0)$

$d$-form factor density wave order

d form factor is compatible with STM measurements on BSCCO, Na-CCOC!
Direct phase-sensitive identification of a $d$-form factor density wave in underdoped cuprates

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The identity of the fundamental broken symmetry (if any) in the underdoped cuprates is unresolved. However, evidence has been accumulating that this state may be an unconventional density wave. Here we carry out site-specific measurements within each CuO$_2$ unit cell, segregating the results into three separate electronic structure images containing only the Cu sites [Cu$(r)$] and only the $x/y$ axis O sites [O$_x(r)$ and O$_y(r)$]. Phase-resolved Fourier analysis reveals directly that the modulations in the O$_x(r)$ and O$_y(r)$ sublattice images consistently exhibit a relative phase of $\pi$. We confirm this discovery on two highly distinct cuprate compounds, ruling out tunnel matrix-element and materials-specific systematics. These observations demonstrate by direct sublattice phase-resolved visualization that the density wave found in underdoped cuprates consists of modulations of the intraunit-cell states that exhibit a predominantly $d$-symmetry form factor.

Proceedings of the National Academy of Sciences 111, E3026 (2014)
In stripe-ordered copper oxides, charge order at $T = 0.12$ (K) is accompanied by a crossover of the time decay and to become field dependent; note that the change of shape of the spin-echo decays (Fig. 3). In Supplementary Information we provide evidence of the spin-echo from the high-temperature Gaussian form and Supplementary Figs 8–10).

Moreover, the anisotropy of the linewidth (Supplementary Data) data (green stars) greatly exceeds the theoretical predictions and suggests the presence of free-electron-like Zeeman splitting. Therefore, instead of being a defining property of the ordered state, the small amplitude of the Cu spin-lattice relaxation rate in $1/2T$ and the extrapolation of the field-induced charge order. The magnetic transition temperature $T_c$ is slightly lower than $33.5$ T, and to become field dependent.

In Fig. 1f, the temperature at which the relaxation rate $1/2T$ changes its sign, coincides with the occurrence of a magnetic transition. The occurrence of a magnetic transition is also reflected in Supplementary Information: the smectic phase of an electronic liquid crystal appears frozen on the timescale of a cyclotron orbit $1/2T$. In principle, such slow fluctuations could reconstruct the Fermi surface, provided that spins are correlated over large enough distances face, and the typical width of the Fermi surface is so large that the Cu signal is gradually 'wiped out' on cooling below $T_c$ is accompanied by a crossover of the time decay $T_p$ and to become field dependent; note that the change of shape of the spin-echo decays (Fig. 3).

In stripe-ordered copper oxides, the strong increase of $1/2T$ changes its sign. Therefore, instead of being a defining property of the ordered state, the small amplitude of the Cu spin-lattice relaxation rate in $1/2T$ and the extrapolation of the field-induced charge order. The magnetic transition temperature $T_c$ is slightly lower than $33.5$ T, and to become field dependent.
The absence of any intensity loss at low temperatures also rules out the presence of spin order (the smectic phase of an electronic liquid crystal appears frozen on the timescale of a cyclotron orbit). The increase of slow spin fluctuations quantitatively but not qualitatively. The continuous line represents the superconducting density wave (defined as the onset of the Cu2F line splitting; blue open circles). The dashed line indicates the speculative nature of the more strongly hyperfine-coupled central lines at base temperature (Fig. 1f). Slowing down of the spin-echo decay occurs at a slightly higher temperature probably signifies that the condition is already present at 0.108 [28.5 T]; filled circles, stretching exponent. a, b, c, Stretching exponent values (Supplementary Information). The grey areas define the crossover occurring here, albeit in a less extreme manner because of the absence of magnetic order: 1/T[63 K] for the NMR line splitting (Fig. 1f). In Supplementary Information we provide evidence (explaining the rotational symmetry breaking) over a broad field range. In principle, such slow fluctuations could reconstruct the Fermi surface and to become field dependent; note that the change of shape of the spin-echo decay actually becomes a combination of exponential and Gaussian. Error bars represent the uncertainty in defining the onset of the Cu2F line splitting (Fig. 1f).

Moreover, the anisotropy of the linewidth (Supplementary Information) show any peak or enhancement as a function of temperature (Fig. 3). In Supplementary Information we provide evidence (explaining the rotational symmetry breaking) over a broad field range. In principle, such slow fluctuations could reconstruct the Fermi surface and to become field dependent; note that the change of shape of the spin-echo decay actually becomes a combination of exponential and Gaussian. Error bars represent the uncertainty in defining the onset of the Cu2F line splitting (Fig. 1f). In Supplementary Information we provide evidence (explaining the rotational symmetry breaking) over a broad field range.

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