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Pressure-induced electronic topological transitions in low dimensional superconductors*

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Abstract

The high- T_c cuprate superconductors are characterized by a quasi-two-dimensional layered structure where most of the physics relevant for high- T_c superconductivity is believed to take place. In such compounds, the unusual dependence of the critical temperature T_c on external pressure results from the combination of the nonmonotonic dependence of T_c on hole doping or hole-doping distribution among inequivalent layers, and from an ‘intrinsic’ contribution. After reviewing our work on the interplay among T_c , hole content, and pressure in the bilayered and multilayered cuprate superconductors, we will discuss how the proximity to an electronic topological transition (ETT) may give a microscopic justification of the ‘intrinsic’ pressure dependence of T_c in the cuprates. An ETT takes place when some external agent, such as doping, hydrostatic pressure, or anisotropic strain, modifies the topology of the Fermi surface of an electronic system. As a function of the critical parameter z , measuring the distance of the chemical potential from the ETT, we recover a nonmonotonic behaviour of the superconducting gap at $T = 0$, regardless of the pairing symmetry of the order parameter. This is in agreement with the trend observed for T_c as a function of pressure and other material specific quantities in several high- T_c cuprates and other low dimensional superconductors. In the case of epitaxially strained cuprate thin films, we argue that an ETT can be driven by a strain-induced modification of the in-plane band structure, at constant hole content, at variance with a doping-induced ETT, as is usually assumed. We also find that an increase of the in-plane anisotropy enhances the effect of fluctuations above T_c on the normal-state transport properties, which is a fingerprint of quantum criticality at $T = 0$.

* EHPRG Award Lecture.

1. Introduction

High pressure research plays an important role in the study of superconducting materials. A surprisingly large number of elemental solids is found to be superconducting under extreme conditions [1], with the recent addition of nonmagnetic iron, with a critical temperature $T_c \sim 2$ K at pressures $P = 15\text{--}30$ GPa [2], and possibly of lithium ($T_c = 20$ K, $P = 48$ GPa) [3, 4]. The case of the ‘simple’ alkali metals under pressure is actually quite interesting by itself. Following earlier theoretical suggestions of an electronic [5] or pairing [6] instability, recent experimental findings actually indicate a metal–insulator transition into a reduced-symmetry phase at $P = 45$ GPa [7–9]. Our recent proposal is that Friedel oscillations in the pair potential may justify phase oscillations between a symmetric phase and a low-symmetry dimerized structure as a function of pressure, with re-entrant metallicity occurring at higher pressures [10].

Here, we will focus on the pressure effects on the superconducting properties of the high- T_c cuprates. These materials are characterized by CuO_2 layers, where most of the physics relevant for high- T_c superconductivity is believed to take place [11]. As a consequence of their reduced dimensionality, hydrostatic pressure as well as uniaxial strain is expected to influence the superconducting properties of the cuprates remarkably. This is usually indicated by the magnitude and sign of the pressure derivative of T_c , dT_c/dP . While in the case of ‘conventional’, phonon-mediated superconductors one almost invariably has $dT_c/dP < 0$, mainly as a result of lattice stiffening [12, 13]¹, the pressure dependence of T_c in the cuprates is usually nonmonotonic, with a sign-changing dT_c/dP , and T_c may even display kinks as a function of pressure [14].

Such a behaviour is usually related to an interplay among T_c , hole doping n , and pressure. Since hole doping is itself a function of pressure, one may generally write [12]

$$\frac{dT_c}{dP} = \frac{\partial T_c}{\partial P} + \frac{\partial T_c}{\partial n} \frac{dn}{dP}, \quad (1)$$

where T_c at ambient pressure follows a universal bell-shaped curve as a function of doping [15]. Equation (1) shows that the actual value and sign of the total derivative dT_c/dP is given by the competition of a hole-driven contribution, and an ‘intrinsic’ contribution, $\partial T_c/\partial P$. The theoretical implications of such a pressure-dependent T_c , and in particular of a nonzero ‘intrinsic’ contribution $\partial T_c/\partial P$, can help in understanding the pairing mechanism of these unconventional superconductors.

In this paper, we will review our results concerning the interplay expressed by equation (1), both for a bilayered cuprate [16] and for multilayered cuprates [17]. In the case of a bilayered cuprate (section 2), after recovering the universal nonmonotonic dependence of T_c on hole doping, we will extract a phenomenological estimate of the ‘intrinsic’ contribution $\partial T_c/\partial P$ by comparison with available experimental data for Bi2212. In the case of multilayered cuprates (section 3), we will emphasize the role of a nonuniform hole-content distribution among inequivalent CuO_2 layers. Two possible sources of inequivalence will be considered, namely a different proximity to the charge-reservoir layers, and the different number of adjacent CuO_2 layers to which a given layer may be coupled by means of interlayer pair tunnelling (ILT) [18–20]. Later, in section 4, we will discuss the microscopic origin of the ‘intrinsic’ pressure dependence of T_c as due to the proximity to an electronic topological transition (ETT) [21–23], which takes place when some external agent (such as pressure) modifies the topology of the Fermi surface of an electronic system. We will eventually summarize in section 5.

¹ A negative pressure derivative dT_c/dP seems to be characteristic also of the non-cuprate compound MgB_2 , which has been recently found to be superconducting with $T_c \sim 40$ K. (See [13]). Such a result would be consistent with a phonon-mediated superconducting mechanism in this material.

2. Interplay among T_c , hole doping, and pressure: bilayered cuprates

In [16], we have analysed a model Hamiltonian describing tightly bound interacting fermions in a bilayer complex:

$$H = \sum_{\mathbf{k}\sigma} \xi_{\mathbf{k}} c_{\mathbf{k}\sigma}^\dagger c_{\mathbf{k}\sigma} + \frac{1}{N} \sum_{\mathbf{k}\mathbf{k}'} V_{\mathbf{k}\mathbf{k}'} c_{\mathbf{k}\uparrow}^\dagger c_{-\mathbf{k}\downarrow}^\dagger c_{-\mathbf{k}'\downarrow} c_{\mathbf{k}'\uparrow}, \quad (2)$$

where $c_{\mathbf{k}\sigma}^\dagger$ ($c_{\mathbf{k}\sigma}$) creates (destroys) a fermion with spin projection σ along a specified direction, wavevector \mathbf{k} belonging to the first Brillouin zone (1BZ) of a tetragonal lattice containing N \mathbf{k} -points, and band dispersion $\xi_{\mathbf{k}} = \epsilon_{\mathbf{k}} - \mu$, measured relative to the chemical potential μ . As for the tight-binding dispersion relation, we assumed the form

$$\epsilon_{\mathbf{k}} = -2t[\cos(k_x a) + \cos(k_y a)] + 4t' \cos(k_x a) \cos(k_y a) - 2t_z \cos(k_z c), \quad (3)$$

which retains in-plane nearest neighbour (t) and next-nearest neighbour (t') hopping, as well as nearest neighbour interlayer single-particle hopping ($t_z \ll t$). The interaction term in equation (2) may be expanded over the different symmetry channels allowed by the C_{4v} symmetry of the lattice. Assuming the interaction kernel to be separable, one has $V_{\mathbf{k}\mathbf{k}'} = \sum_h \lambda_h g_{\mathbf{k}}^{(h)} g_{\mathbf{k}'}^{(h)}$, where λ_h are phenomenological coupling constants, $g_{\mathbf{k}}^{(0)} = 1$ and $g_{\mathbf{k}}^{(1)} = \frac{1}{2}[\cos(k_x a) + \cos(k_y a)]$ correspond to s-wave symmetry, and $g_{\mathbf{k}}^{(2)} = \frac{1}{2}[\cos(k_x a) - \cos(k_y a)]$ corresponds to d-wave symmetry [16, 19].

A mean-field analysis of equation (2) as a function of hole content allowed us to recover the universal, nonmonotonic doping dependence of T_c at ambient pressure [15]. This seems to be a generic feature of a dispersion relation like equation (3), as we will comment later on in section 4. While superconductivity sets in with a definite symmetry (either s- or d-wave) at $T = T_c$, with d-wave prevailing for hole contents larger than or equal to optimal doping, symmetry mixing is allowed at low temperature and intermediate dopings [16, 19]. The role of the symmetry of the order parameter in determining the scale of T_c in both high- T_c superconductors and heavy fermion compounds has been discussed in [24–26].

Such an analysis has been generalized for a nonzero applied pressure P . The effect of pressure is mainly that of decreasing the lattice constants a and c , thus varying the band parameters t , t' , t_z , and of changing the hole content n , thus varying the chemical potential μ . While the pressure dependence of the lattice parameters may be extracted from the available components of the isothermal compressibility tensor κ_i ($i = x, y, z$), the pressure dependence of the overall hole content can be derived from available data for the Hall resistance as a function of pressure [27]. Application of hydrostatic pressure results in widening of the electronic band, and in a decrease of the density of states, due to a reduction of the would-be Van Hove singularity (figure 1).

By comparison with the available pressure dependence of T_c in Bi2212 [27], we could extract a phenomenological estimate of the ‘intrinsic’ contribution $\partial T_c / \partial P$ to the total pressure derivative of T_c in equation (1) (figure 1). Such a contribution turns out to be nonnegligible, especially at lower pressures, and justifies a sign changing overall dT_c/dP with increasing pressure.

3. Interplay among T_c , hole distribution, and pressure: multilayered cuprates

In order to study the case of multilayered cuprate compounds, such as the homologous series $\text{Bi}_2\text{Sr}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2n+4+y}$ (Bi-2:2:($n-1$): n , whereof Bi2212 is the bilayered instance, with $n = 2$), $\text{Tl}_m\text{Ba}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2(n+1)+m+y}$ (Tl- m :2:($n-1$): n , with $m = 1, 2$), or $\text{HgBa}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_{2n+2+y}$ (Hg-1:2:($n-1$): n), we have to generalize the above model in order to take into

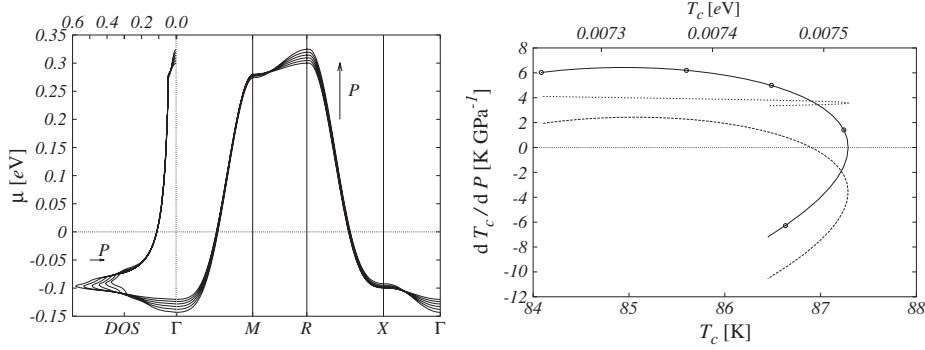


Figure 1. Left: band dispersion along a symmetry contour of the 1BZ, equation (3), and density of states as a function of pressure $P = 0\text{--}20$ GPa. Right: pressure derivatives of T_c for $P = 0\text{--}1.6$ GPa. Solid curve: best fit to the experimental data of Huang *et al* [27]; dashed curve: hole induced contribution; dotted curve: our estimate for the ‘intrinsic’ contribution, $\partial T_c / \partial P$ (equation (1)). Redrawn after [16].

account the inequivalence among different layers. In [17] we have considered basically two sources of inequivalence among different layers.

First of all, a different proximity to the ‘charge reservoir’ layers may induce a nonuniform hole-content *distribution* between inner and outer CuO_2 layers. This may be taken into account by assuming a model electronic band in each layer as in equation (3), but now with a chemical potential μ^ℓ depending on layer index ℓ .

In addition to that, inner CuO_2 layers are expected to be coupled more intensely to adjacent layers than to outer layers. An intensely debated proposal for the origin of interlayer coupling in the cuprates is the interlayer pair tunnelling (ILT) model [18, 11, 19, 20].

The ILT mechanism of high- T_c superconductivity has been proposed as a possible explanation for the observed high values of T_c in the layered cuprates, as well as a number of other more difficult but related aspects of their complex phenomenology [11]. The ILT mechanism relies on the fact that single-particle coherent tunnelling between adjacent layers is suppressed, due to the so-called Anderson orthogonality catastrophe [11]. Such an assumption amounts to setting $t_z = 0$ in equation (3) above. On the other hand, coherent tunnelling of Cooper *pairs* does not suffer from such restrictions, and thus enters the total Hamiltonian as a second order effect in the single particle hopping matrix element $t_\perp(\mathbf{k})$ [18]. While within conventional models the superconducting state is accessed by lowering the potential energy of the electronic system, the main aspect of the ILT mechanism is that Josephson tunnelling of Cooper pairs between adjacent CuO_2 layers allows the system to access the normal-state frustrated c -axis kinetic energy. However, the ILT mechanism has been recently deeply reconsidered, due to its apparent inconsistency with the observed c -axis electrodynamics [28–30].

In the presence of ILT between adjacent layers, the interaction term in equation (2) should be modified as

$$\frac{1}{N} V_{\mathbf{k}\mathbf{k}'} \mapsto \tilde{V}_{\mathbf{k}\mathbf{k}'}^{\ell\ell'} = \frac{1}{N} V_{\mathbf{k}\mathbf{k}'} \delta_{\ell\ell'} - T_J(\mathbf{k}) \delta_{\mathbf{k}\mathbf{k}'} (1 - \delta_{\ell\ell'}) \theta(1 - |\ell - \ell'|), \quad (4)$$

where $\theta(\tau)$ is the usual Heaviside step function, $V_{\mathbf{k}\mathbf{k}'}$ is the in-plane potential, now allowing for d-wave pairing only, and $T_J(\mathbf{k}) = t_\perp^2(\mathbf{k})/t$ is the ILT effective interaction [18, 17]. A standard mean-field treatment of the ensuing Hamiltonian yields a system of *coupled* nonlinear equations for the gap function $\Delta_{\mathbf{k}}^\ell$ on layer ℓ ($\ell = 1, \dots, n$). Therefore, linearization of these equations close to T_c admits in principle n solutions, $T_c = T_c^{(\ell)}$, say, corresponding to an incipiently

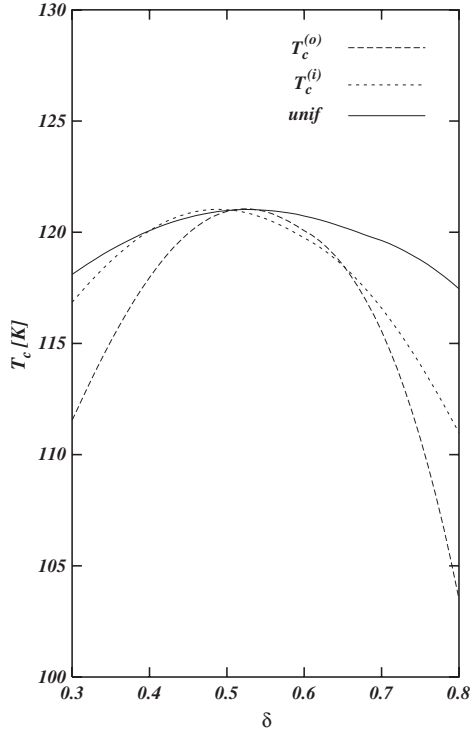


Figure 2. Critical temperatures $T_c^{(i,o)}$ for inner and outer layers in the case of an $n = 3$ layered complex, as a function of the overall doping δ . A nonuniform hole-content distribution among inequivalent layers has been assumed, according to the point-charge model. The solid curve corresponds to the uniform distribution. A crossover from superconductivity arising from inner or outer layers manifests itself as a kink in the doping dependence of $T_c = \max_{\ell} T_c^{(\ell)}$. Redrawn after [17].

nonzero gap $\Delta_{\mathbf{k}}^{\ell}$ on layer ℓ . The ‘physical’ solution for the critical temperature T_c is then simply $T_c = \max_{\ell} T_c^{(\ell)}$, corresponding to the gap which first opens as T decreases towards T_c .

The result of our numerical solutions of the equations for $T_c^{(\ell)}$ are shown in figure 2, where we have assumed a nonuniform hole-content distribution among inequivalent layers according to the point-charge model [31]. Such a model estimates the hole contents within inner and outer layers as a function of overall doping δ by minimizing the total carrier energy in the layered complex, expressed as a sum of band energy, plus electrostatic energy, where the charge distribution within a given layer is described as localized on the constituent ions of the unit cell [31]. From figure 2, it turns out that, as a function of overall doping δ (which can be varied by means of applied pressure), a crossover takes place between superconductivity arising from inner and outer layers. These crossovers manifest themselves as *kinks* in the doping dependence (pressure dependence) of T_c , as is experimentally observed in many layered cuprate superconductors [14].

4. The effects of proximity to an electronic topological transition

Applied pressure can modify the properties of a bulk metal by changing the topology of its Fermi surface (FS), as was earlier recognized by Lifshitz [32]. Lifshitz coined the term electronic topological transition (ETT) in order to describe the anomalies in several electronic properties at $T = 0$ induced by a change of the connectivity number of the FS. An ETT can be driven by several external agents, such as isotropic pressure, anisotropic deformation, and the introduction of isovalent impurities. In all these cases, it is customary to employ a single critical parameter $z = \mu - \epsilon_c$, measuring the distance of the chemical potential μ from the critical value ϵ_c , corresponding to the transition. As $z \rightarrow 0$, several normal-state electronic properties, such as conductivity, specific heat, thermoelectric power, thermal expansion and sound absorption

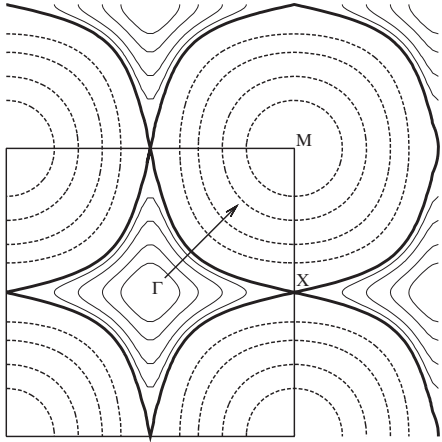


Figure 3. Typical Fermi lines of a high- T_c superconductor as a function of doping. See the text for discussion.

coefficients, exhibit an anomalous behaviour, characterized by the appearance of a step or a cusp-like z -dependence [33, 34].

ETT's are also possible in fermion systems characterized by a low effective dimensionality. This is possibly the case for the high- T_c cuprates and for the κ -(BEDT-TTF)₂-X organic salts [35]. Figure 3 displays the typical Fermi lines of a high- T_c cuprate superconductor, such as LSCO, in the first and adjacent Brillouin zones ($-\pi \leq k_x, k_y \leq 2\pi$). These correspond to $\xi_{\mathbf{k}} = 0$ in equation (3) (now with $t_z = 0$ and $t'/t = 0.45$). As the chemical potential μ increases from the bottom to the top of the band, an ETT is traversed as soon as the FS touches the borders of the 1BZ. Correspondingly, the Fermi line evolves from a closed, electron-like, to an open, hole-like, contour, with respect to the Γ point in the 1BZ. Exactly the same kind of patterns have recently been observed experimentally, by means of angular-resolved photoemission spectroscopy (ARPES), in LSCO as a function of doping [36]. Close to the ETT, the band dispersion equation (3) can be approximated by a locally hyperbolic dispersion relation, $\epsilon_{\mathbf{k}} - \epsilon_c \approx p_1^2/(2m_1) - p_2^2/(2m_2)$, with $p_1 = k_x$, $p_2 = k_y - \pi$, $\epsilon_c = -4t'$, and $m_{1,2} = [2t(1 \pm 2r)]^{-1}$, the fine details thereof being determined by the value of the next-nearest neighbours to nearest neighbours hopping ratio, $r = t'/t$ [37, 21]. In order to have a flat minimum in $\xi_{\mathbf{k}}$ around the Γ point, as is observed experimentally for the majority of the cuprates, the condition $0 < r < \frac{1}{2}$ must be fulfilled. A universal, direct correlation between optimal doping T_c^{\max} and the hopping ratio r of several cuprate compounds has been earlier recognized by Pavarini *et al* [38], thus showing that in-plane anisotropy, corresponding to a relatively large value of the hopping ratio r , enhances superconductivity.

The first and foremost effect of an ETT in the spectrum of a quasi-2D pure electronic system is that of producing a logarithmic Van Hove singularity in the density of states (DOS) each time the Fermi level traverses a saddle point in the dispersion relation [39–41]. Due to the effect of impurities, however, such a singularity is smeared into a pronounced maximum with finite height [21]. Moreover, two close singularities, such as those resulting from a pressure-induced tetragonal to orthorhombic distortion of the lattice in the cuprates, are expected to merge into a single, broader maximum.

As a consequence of the presence of an ETT in the electronic spectrum, the gap magnitude Δ_0 at $T = 0$ is characterized by a nonmonotonic dependence on the critical parameter z . Within a mean-field approach to a model Hamiltonian like equation (2), we derived such a result, both analytically [21] and numerically [22], both in the s - and in the d -wave case. In view of the fact that $T_c \propto \Delta_0$, as in any mean-field theory, such a finding is in agreement with the

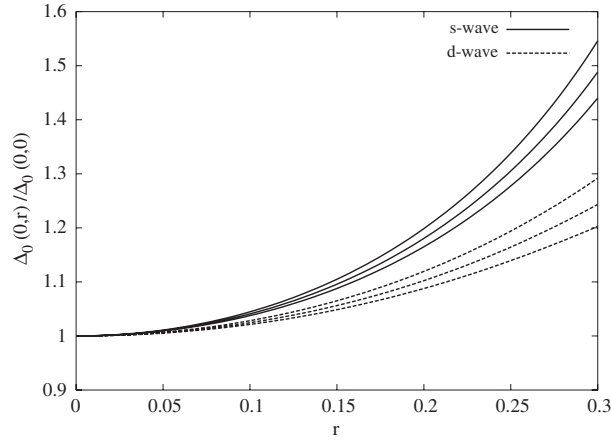


Figure 4. Normalized gap amplitude $\Delta_0(z=0, r)/\Delta_0(z=0, r=0)$ at $T=0$, as a function of the hopping ratio $r = t'/t$, for different electron–electron couplings ($\lambda = 0.9$ – 1.1 , increasing from bottom to top). Solid curves refer to the s-wave case, while dashed curves refer to the d-wave case. One can recognize the direct correlation between $T_c^{\max} \propto \Delta_0(z=0)$ and r , as argued by Pavarini *et al* [38]. Redrawn after [21].

phenomenology of the high- T_c cuprates [15, 14]. We could also estimate the maximum gap at $T=0$, which is expected to scale with T_c^{\max} , as the value of Δ_0 close to the ETT ($z=0$). Our analytical results for $\Delta_0(z=0)$ as a function of the hopping ratio r are shown in figure 4. One can recognize the direct correlation between $T_c^{\max} \propto \Delta_0(z=0)$ and r , as argued by Pavarini *et al* [38]. Such a correlation results to be universal, in the sense that it does not depend on the symmetry of the order parameter and on the coupling strength, but rather looks like a generic consequence of the proximity to an ETT at $T=0$.

The ‘intrinsic’ effect of applied pressure on T_c has probably been singled out in the epitaxial strain experiments of Locquet *et al* [42] on LSCO thin films. These workers investigated the effect of tensile and compressive epitaxial strains on the transport properties of $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ (LSCO) thin films, which were epitaxially grown on a SrLaAlO_4 (SLAO) substrate, characterized by an in-plane lattice spacing slightly smaller than that of LSCO ($a_{\text{LSCO}} = 3.777 \text{ \AA}$, $a_{\text{SLAO}} = 3.755 \text{ \AA}$). It was shown that such an in-plane compressive strain increased T_c up to 49 K in slightly underdoped LSCO ($x = 0.11$). This important finding is so much more interesting, since in the LSCO compound the hole concentration is mostly determined by the Sr content, together with a small oxygen non-stoichiometry, and seems to be little depending on pressure [43]. In other words, the condition $dn/dP = 0$ seems to apply to equation (1), so that the total pressure derivative of T_c can be attributed only to ‘intrinsic’ effects.

Within a Ginzburg–Landau phenomenological model, we have discussed the dependence of T_c on the microscopic strains for a tetragonal cuprate superconductor [22]. For small strains, we found a monotonic increase of T_c with increasing size of the CuO octahedron, whereas we found a nonmonotonic dependence of T_c on either apical or in-plane microstrains, as well as on hydrostatic pressure, in agreement with the phenomenology of the high- T_c cuprates [22]. Moreover, under epitaxial strain ε_{epi} , we found a monotonically decreasing T_c in the experimentally accessible range $-0.006 \leq \varepsilon_{\text{epi}} \leq 0.006$, with a sharp maximum just below the lower bound of the range [22], in good qualitative and quantitative agreement with the experimental results for epitaxially strained LSCO [42].

From a microscopic point of view, a nonmonotonic strain dependence of the critical temperature in the high- T_c cuprates may be interpreted as due to the proximity to an ETT.

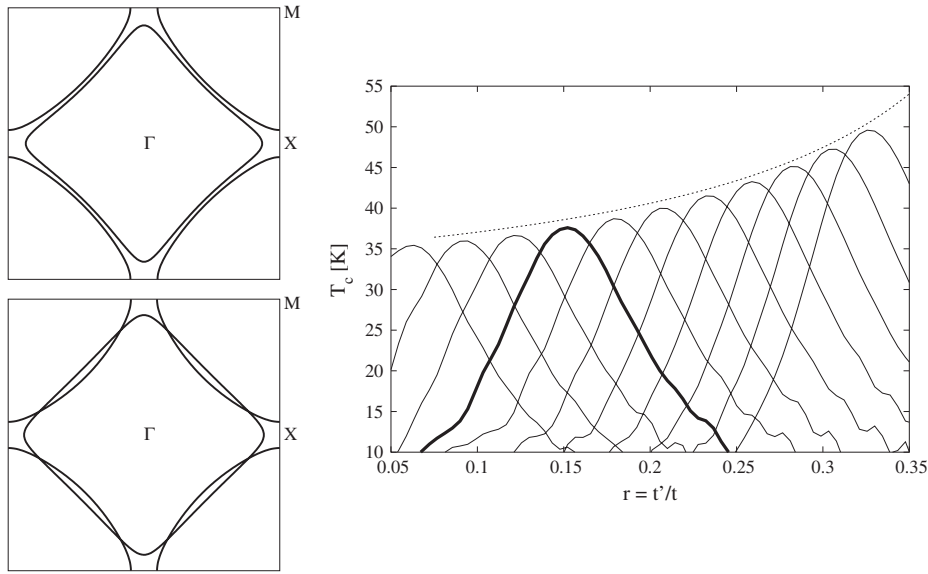


Figure 5. Left: typical Fermi lines $\xi_{\mathbf{k}} = 0$, equation (3), at either side of an ETT. Left, top panel: hole-content driven ETT, at constant hopping ratio ($r = 0.182$). Left, bottom panel: strain-induced ETT, at constant hole concentration ($\delta = 0.125$, close to optimal doping). Right: the critical temperature T_c as a function of the hopping ratio $r = t'/t$. Along each curve, the hole concentration has been kept equal to a constant value ($\delta = 0.05$ – 0.3 , with $\delta = 0.125$ for the thicker curve). The dashed curve is a guide for the eye for the dependence of T_c^{\max} on the hopping ratio r . Redrawn after [22].

In spite of being induced by a change in the hole concentration, as is usually assumed, here we considered a change of topology of the Fermi line as due to a strain-induced variation of the band parameters, such as the next-nearest to nearest neighbours hopping ratio $r = t'/t$, at constant doping. Figure 5 shows how an ETT may be driven by a change in r , at constant hole doping δ . One recognizes a nonmonotonic dependence of T_c on strain, through the hopping ratio r , the maximum in T_c being attained close to the ETT. One also recovers the direct correlation between T_c^{\max} and the hopping ratio r [38, 21, 22].

We have also studied the effects of the proximity to an ETT on several normal-state properties of the high- T_c cuprates [21, 23]. In the normal state just above T_c , the effect of the fluctuations can contribute to a better understanding of the unconventional properties of these materials [44, 45]. In particular, most experimental findings can be interpreted as an effect of precursor pairing above T_c in the pseudogap region (see, e.g., [46], and references therein).

In the case of several transport properties in the normal state, such as the Ettinghausen effect, the Nernst effect, the thermopower, the electrical conductivity, and the Hall conductivity, the effect of fluctuations above T_c can be embodied in the relaxation rate γ of the order parameter within the time-dependent Ginzburg–Landau (TDGL) theory for a layered superconductor [45, 47]. In particular, a nonzero imaginary part of such a quantity can be related to an electron–hole asymmetry of the band structure [48–50], as is the case with a nonzero hopping ratio $r = t'/t$ in equation (3). We have evaluated $\text{Im } \gamma$ close to an ETT, both numerically and analytically, in the relevant limits, as a function of the critical parameter z and temperature [23]. We found that $\text{Im } \gamma$ is a sign-changing function of z , with two peaks occurring on both sides of the ETT, whose absolute value increases with increasing r .

On the one hand, the anomalous behaviour of $\text{Im } \gamma$ close to an ETT is a fingerprint of quantum criticality at $T = 0$, and is suggestive of the fact that an ETT at $T = 0$ may be

the source of quantum critical fluctuations at the basis of the phase diagram of the high- T_c cuprates [51–55]. On the other hand, the direct correlation of $|\text{Im}\gamma_{\text{peaks}}|$ on the hopping ratio r is in agreement with the universal behaviour of the fluctuation Hall effect in the cuprates [23], and is again an indication that in-plane anisotropy enhances superconductivity.

5. Summary and concluding remarks

We have reviewed our results concerning the pressure dependence of the critical temperature T_c in the high- T_c cuprate superconductors. Within a mean-field approach to model Hamiltonians, we have evaluated T_c as a function of hole content for a bilayered cuprate, and as a function of hole-content distribution for a multilayered cuprate, characterized by inequivalent layers. In the case of a bilayered cuprate, by comparison with available experimental data for Bi2212 under pressure ($P = 0\text{--}1.6$ GPa), we were able to provide a phenomenological estimate of the ‘intrinsic’ contribution $\partial T_c/\partial P$ to the total pressure derivative of T_c , dT_c/dP [12]. In the case of a multilayered cuprate, the crossover among the ‘critical temperatures’ associated to superconductivity setting in inequivalent layers as a function of the overall hole content is in agreement with the observed kinks in T_c as a function of pressure for these layered cuprates ($P = 0\text{--}40$ GPa) [14].

We eventually proposed a microscopic interpretation of the observed pressure dependence of T_c , particularly of its ‘intrinsic’ dependence, in terms of the proximity to an electronic topological transition. Instead of an ETT induced by a change in the hole content, as is usually assumed, we considered a strain-induced ETT, as is possibly the case in recent experiments in epitaxially strained LSCO [42]. In this case, epitaxial strain may induce a change of the topology of the Fermi line by modifying the in-plane band parameters, at constant hole doping. Our results for the dependence of T_c and the anomalous size of some fluctuation transport properties above T_c on the hopping ratio r is in agreement with the universal behaviour of the high- T_c cuprates. In particular, an increase of the in-plane anisotropy enhances superconductivity.

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