The electronic structure of the high-$T_c$ cuprates is studied on the basis of both “large-$U$” and “small-$U$” orbitals. A striped structure is obtained, and three types of carriers: polaron-like “stripons” carrying charge, “quasielectrons” carrying charge and spin, and “svivons” carrying spin and lattice distortion. Anomalous properties of the cuprates and specifically their transport properties are derived. Pairing is found to result from transitions between pair states of quasielectrons and stripons through the exchange of svivons. The pairing results in superconductivity when the stripons conduction is coherent, and in a pseudogap phase when it is not.

Both “large-$U$” and “small-$U$” orbitals are considered in the vicinity of the Fermi level ($E_F$) of the high-$T_c$ cuprates. The large-$U$ orbitals are treated using the “slave-fermion” method, where the electrons are described in terms of auxiliary particles: fermion ”holons” and boson ”spinons”. An extended auxiliary Hilbert space is introduced, and physical observables are expressed in terms of the auxiliary-space Green’s functions.

Bose condensation of the spinons results in antiferromagnetism (AF). It has been shown that a lightly doped AF plane segregates into AF stripes and narrower “charged” stripes forming antiphase domain walls between them. Such a scenario is supported by experiment, and there exists growing evidence that it probably exists, at least dynamically on the short range, in all the superconducting cuprates.

Spin-charge separation applies along the one-dimensional charged stripes (where such an approximation is known to be valid), and holons within them are referred to as “stripons”, carrying charge, but not spin. Since the stripes in the cuprates are disordered, and consist of disconnected segments, it is assumed here that an appropriate starting point is of localized stripon states.

Other carriers (of both charge and spin) result from the hybridization of small-$U$ states and coupled holon-spinon states which are orthogonal to the stripon states. These carriers as referred to as “Quasi-electrons” (QE’s), and their bare energies form quasi-continuous ranges of bands crossing $E_F$.

These fields are coupled to each other due to hopping and hybridization terms of the orbitals, and the coupling can be expressed in terms of an effective Hamiltonian.
It introduces a vertex between the QE, stripon, and spinon propagators, and “vertex corrections” are negligible by a generalized Migdal theorem. For sufficiently doped cuprates the self-consistent self-energy corrections determine quasiparticles of the following features:

The spinon spectral functions are proportional to $\omega$ for small $\omega$, resulting in the absence of long-range AF order (though short-range order persists). The energies of the localized stripon states are renormalized to a very narrow range around zero, thus getting polaron-like states. Some hopping via QE-spinon states results in the onset of coherent itineracy at low temperatures, with a bandwidth of $\sim 0.02$ eV. The stripon scattering rates scale as: $\Gamma_p(k, \omega) \propto A\omega^2 + B\omega T + CT^2$. The QE scattering rates scale as: $\Gamma_q(k, \omega) \propto T$ for $T \gg |\omega|$, and $\Gamma_q(k, \omega) \propto \frac{1}{2} |\omega|$ for $T \ll |\omega|$, in agreement with “marginal Fermi liquid” phenomenology.

It was found that the charged stripes are characterized by LTT structure, while the AF stripes are characterized by LTO structure. The result would be that spinons are “dressed” by phonons when they are emitted or absorbed in processes where a stripon is transformed into a QE, or vice versa. Such a phonon-dressed spinon is referred to as a “svivon”, and it carries spin and lattice distortion.

The optical conductivity of the doped cuprates has two components, a Drude term and mid-IR peaks. The Drude term is due to transitions between QE states, while the mid-IR peaks are due to excitations of stripon states. The electronic spectral function, measured in photoemission experiments, has a “coherent” part, due to the contributions of few QE bands, and an “incoherent” part of a comparable weight, due to the contributions of other quasi-continuous QE bands, and stripon-svivon states. The observed “Shadow bands” and “extended” van Hove singularities result from the effect of the striped superstructure on the QE bands.

The electric current is expressed as a sum $j = j_q + j_p$ of QE and stripon contributions. Since stripons transport occurs through transitions to intermediate QE-svivon states, one gets $j_p \cong \alpha j_q$, where $\alpha$ is approximately $T$-independent. In order for this condition to be satisfied gradients of the QE and stripon chemical potentials must be formed in the presence of an electric field or a temperature gradient.

It has been shown that the temperature dependence of the electrical resistivity can then be expressed as $\rho = (D + CT + A + BT^2)/N$, and of the Hall constant as $R_H = \rho / \cot \theta_H$, where $(\cot \theta_H)^{-1} = Z(D + CT)^{-1} + (A + BT^2)^{-1}$. The $(D + CT)$ and $(A + BT^2)$ terms are (respectively) due to the QE and stripon scattering rates discussed above (to which temperature-independent impurity scattering terms are added). These expressions reproduce the systematic behavior of the transport quantities in different cuprates.

It has also been shown that the thermoelectric power (TEP) $S$ can be expressed in terms of QE and stripon terms as $S = (N^q S^q + N_p S^p)/(N^q + N_p)$, where $S^q \propto T$, while the stripon term saturates at $T \approx 200$ K to $S^p = (k_B/e) \ln [(1 - n_p)/n_p]$. This result is consistent with the typical behavior of the TEP in the cuprates.

The present approach provides a pairing mechanism involving transitions between pair states of QE’s and stripons through the exchange of svivons. This is con-
ceptually similar to the interband pair transition mechanism proposed by Kondo. A condition for superconductivity is that the narrow stripon band maintains coher-
ence between different stripe segments. Pairing can, however, occur also when the
stripons are incoherent, and the condensate is then interpreted as the pseudogap
phase found in underdoped cuprates.

Thus a normal-state pseudogap is expected to have a similar size and symmetry
to that of the superconducting gap, as has been observed, and its opening accounts
for most of the pair-condensation energy, as has been observed too. In overdoped
cuprates, where pairing occurs when the stripon states are coherent, a BCS-like
behavior of the gap is expected, as has been observed.

Stripon coherence is energetically favorable at temperatures where there is a
clear distinction between occupied and unoccupied stripon band states. Thus, an
estimate for the coherence temperature for an almost empty (full) stripon band is
given by the distance $E_F$ of the Fermi level from the bottom (top) of the band at $T = 0$. This result agrees with the “Uemura plots”. The “boomerang-type” behavior
of the Uemura plots in overdoped cuprates is consistent with a transition from a
stripon band top to a band bottom with BCS-type behavior.

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