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Electron or Hole Liquids Flowing Through Antiferromagnetic Assemblies: Proposed Test of *t-J* Model for High *T<sub>c</sub>* Materials N. H. March<sup>a</sup>

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## LETTER

# ELECTRON OR HOLE LIQUIDS FLOWING THROUGH ANTIFERROMAGNETIC ASSEMBLIES: PROPOSED TEST OF *t-J* MODEL FOR HIGH *T<sub>c</sub>* MATERIALS

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#### (Received 30 October 1995)

Li and Gong have recently demonstrated noncanonical Fermi liquid behaviour in doped two-dimensional antiferromagnets described by the t-J model. Here we stress the experimentally established correlation in underdoped YBa<sub>2</sub>Cu<sub>4</sub>O<sub>8</sub> that  $RT_1 \propto T$  over a substantial temperature range, R being the electrical resistivity and  $T_1$  the nuclear spin-lattice relaxation time. While this linearity is consistent with Fermi liquid theory, a test of the validity of the t-J model to describe the normal state of high  $T_c$ materials will be to study whether such behaviour can also result from its noncanonical Fermi liquid characteristics.

KEY WORDS: Doped two-dimensional antiferromagnets, hole liquids, spin excitations.

In a recent paper, Li and Gong<sup>1</sup> have used the so-called *t-J* model to discuss the interaction between holes and spin excitations. They argue convincingly that, in this particular model, one is thereby led to 'noncanonical' Fermi-liquid behaviour for holes in doped two-dimensional antiferromagnets. We have no criticism at all to make of the results they present from their theoretical study of this model. Rather, we shall stress some experimental facts and correlations to which we have recently drawn attention<sup>2-4</sup>. At very least, these urge caution in replacing Fermi liquid theory of the normal state of the high  $T_c$  superconductors by the noncanonical Fermi-liquid behavior demonstrated by Li and Gong<sup>1</sup> to follow from the *t-J* model. Thus, as the focus for the present Letter, we quote Li and Gong<sup>1</sup> as saying that "the anomalous normal-state properties in the high- $T_c$  cuprates are difficult to explain in the framework of the conventional Landau Fermi-liquid theory".

Returning now to the above comment on high  $T_c$  experiments, we have earlier discussed the properties of electron or hole liquids flowing through antiferromagnetic assemblies<sup>2,3</sup>. In this work, we found valuable the two-dimensional

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Fermi-liquid theory of Kohno and Yamada<sup>5</sup> as motivation. These workers derived two formulae of particular relevance in the present context, namely

$$R \propto T^2 \chi(\mathbf{Q}) \tag{1}$$

and

$$(T_1 T)^{-1} \propto \chi(\mathbf{Q}). \tag{2}$$

In Eqns. (1) and (2), R and  $T_1$  are respectively the electrical resistivity and the nuclear spin-lattice relaxation time. Finally  $\chi(\mathbf{Q})$  is the wave-vector dependent magnetic susceptibility evaluated at the antiferromagnetic wave-vector  $\mathbf{Q}$ . As emphasized by Egorov and March<sup>3</sup>, while suitable data is not presently available on any one specific high  $T_c$  material in the normal state to test Eqns. (1) and (2) separately, if one eliminates  $\chi(\mathbf{Q})$  between them the clearcut prediction

$$RT_1 \propto T$$
 (3)

emerges. This can indeed be tested using only experimental data on R and  $T_1$  for underdoped YBa<sub>2</sub>Cu<sub>4</sub>O<sub>8</sub>, and the resulting plot of  $RT_1$  versus T is shown in Figure 1 of Egorov and March<sup>3</sup>. There is a substantial range of temperature over which the prediction (3) of two-dimensional Fermi liquid theory is vindicated, above a certain 'crossover' temperature. Following the theoretical arguments of Noziéres and Schmitt-Rink<sup>6</sup>, given before the high  $T_c$  cuprates were discovered<sup>7</sup>, we have interpreted the crossover occurring before the transition temperature  $T_c$  as heralding the formation of charged (2e) Bosons<sup>4</sup>. These then serve as the precursor of the superconducting transition.

The point we emphasize therefore is that before Li and Gong<sup>1</sup> can interpret their noncanonical Fermi liquid results for the *t-J* model as relevant to describe the physics of the high  $T_c$  cuprates in the normal state, it is important to bring their theory into contact with the facts displayed in Figure 1 of reference 3. If these can also be explained within the framework of noncanonical Fermi-liquid behavior, then that would greatly enhance confidence that the *t-J* model contains within itself the essential physics of high  $T_c$  normal-state properties.

It is a pleasure to thank Mr. S. A. Egorov (Wisconsin), and Professors G. Baskaran (Madras) and R. Pucci (Catania) for numerous valuable discussions on the general area embraced by this Letter.

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