NUCLEAR SPIN RELAXATION AND INCOMMENSURATE MAGNETISM IN DOPED CUPRATES

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Abstract Existing data on ^{63}Cu-nuclear spin relaxation reveal two independent relaxation processes: the one that is temperature independent we link to incommensurate peaks seen by neutrons, while the "universal" temperature dependent contribution coincides with $1/^{63}T_1(T)$ for two-chain YBCO 124. We argue that this new result substitutes for a "pseudogap" regime in a broad class of high-T_c cuprates and stems from the 1st order phase transition that starts well above the superconductivity T_c but becomes frustrated because of broken electroneutrality in the CuO_2 plane.

Keywords: superconductivity, pseudogap, magnetic properties, NMR

One of the most intriguing normal properties of the high-T_c (HT_c) cuprates is the so called "pseudogap" (PG) phenomenon. It is commonly presented in the (T, x) plane as a line that starts from rather high temperatures (at small x) and reaches the superconductivity (SC) T_c "dome" below at or above optimal $x \sim 0.16$. In a broad sense x means the hole concentration in the CuO_2- plane, but more often than not one refers to properties of the Sr-doped $La_{2-x}Sr_xCuO_4$ The PG feature was seen in numerous experiments (NMR, tunneling spectra, resistivity etc.; see for example reviews [1, 2]). It has been stressed [3] that the PG temperature is not defined unambiguously.

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A widespread view is that the feature comes from some crossover in the electronic density of states (DOS). The main result of the present paper is that after a proper re-arrangement of the experimental data no PG feature exists in the ^{63}Cu nuclear spin relaxation time behaviour. Instead, the data show two independent parallel relaxation mechanisms: a temperature independent one that we attribute to stripes caused by the presence of external dopants and an "universal" temperature dependent term which turns out to be exactly the same as in the stoichiometric compound YBCO 124.

We attempt below to put the results in the context of a phase separation [4]. The decomposition of $1/^{63}T_1(T,x)$ into two terms, as it will be discussed below in more details, manifests itself in a broad temperature interval above T_c. It is limited from above by a T^* that depends on the concentration, x. We consider T^* defined in this way as a temperature of a 1st order phase transition, which, however, cannot complete itself in spatial coexistence of two phases because of the electroneutrality condition [5]. It was already argued in [4] that such a frustrated 1st order phase transition may actually bear a dynamical character. The fact that a single resonant frequency for the ^{63}Cu nuclear spin is observed in the NMR experiments, confirms this suggestion. Although in what follows, we use the notions of the lattice model [4, 5], even purely electronic models [6–9] for cuprates may reveal a tendency to phase separation.

The basic assumption in [4, 5] are the following. At large enough doping holes move between coppers and oxygens. Spins in the system are d^9-holes trapped to the Cu-sites at the expense of local lattice distorsions. Elastic attractive interactions between these distorsions give rise to a lattice driven frustrated transition below some T^*. Exchange interactions, as in the parent La_2CuO_4, tend to organize the Cu-spins in the antiferromagnetic (AF) sub-phases. Excess charge of the dopants' ions in AF regions must be compensated by accumulation of holes in "metallic" regions.

We now turn to experimental data. In what follows we address only $1/^{63}T_1$ behaviour because for cuprates AF fluctuations prevail over the Korringa mechanisms.

In Fig. 1a we collected data on $1/^{63}T_1$ in LSCO from [10]. Note the following: 1) according to [11] $1/^{63}T_1(T)$ at higher temperatures tends to 2.7 msec^{-1} *for all* Sr concentrations, in spite of considerable spread seen in Fig. 1a. Beginning of deviation from that value could serve us as a definition of $T^*(x)$; 2) note that dissipation $1/^{63}T_1$ monotonically decreases from small x to 0.24; 3) after an appropriate *vertical* offset all curves in Fig. 1a collapse onto the T dependence of $1/^{63}T_1$ for the "optimal" $x = 0.15$ above 50 K (Fig. 1b). We have checked that last