SEARCH FOR MAGNETIC FLUCTUATIONS IN SUPERCONDUCTING $La_{1.83}Sr_{0.17}CuO_4$ BY POLARIZED NEUTRON SCATTERING

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The discovery of high-T_c superconductivity in La(Sr)CuO_4 by Bednorz and Muller /1/ has stimulated an enormous number of experimental and theoretical works on CuO_2-based superconductors. A number of theories considers the exchange interaction of Cu^{2+} ions as a new possible mechanism for superconductivity. For example, P. W. Anderson /2/ has proposed that superconductivity in La_2CuO_4 doped with barium or strontium arose from short range antiferromagnet correlations between copper spins. A «magnetic frustration model» for superconductivity has been proposed by R. Birgenau et al. /3/. A «spin density wave» model for superconductivity is extensively discussed in literature as well /4/. Theoretical studies in this direction were especially stimulated by the experiment giving evidence of the long-range antiferromagnetic ordering in pure La_2CuO_4 below 300 K/5/. It has also been shown that there existed two-dimensional antiferromagnetic correlations of Cu^{2+} spins over distances 200 Å even far above the Neel temperature T_N at which the true long-range antiferromagnetic order sets in /6,7/. The typical fluctuation life time obtained in the experiment was by orders of magnitude shorter than that usually observed in antiferromagnetic systems with comparable correlation lengths. This strongly fluctuating spin state in La_2CuO_4 was called «quantum spin liquid» and was explained within the framework of P. Anderson's RVB-theory /2/.

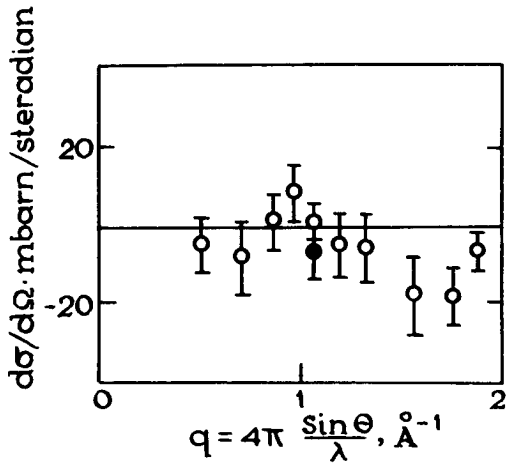

Fig. The magnetic differential cross-section per formula unit as a function of momentum trasfer q at 11K (open circles) and at room temperature (closed sircles)

However, as far as we know, there is still no clear experimental evidence for the existence of magnetic fluctuations in doped La_2CuO_4 exhibiting superconducting properties. Moreover, in the experimental search for magnetic fluctuations in another high-T_C superconductor $YBa_2Cu_3O_7$ no indication of the magnetic scattering was found /8/. Therefore, the aim of our work was to verify the existence of magnetic fluctuations in superconducting $La_{1.83}Sr_{0.17}CuO_4$ by polarized neutrons.

The experiment was carried out in the inversed scattering geometry. Incident neutron beam with a wide energy distribution (4 meV$<E_0<$40 meV) was polarized by Fe—CO neutron guide. The transmission coefficient of the guide was close to unity and the average polarization effeciency was $\langle P_P \rangle = 0.97$. Neutron monochromatization (E_f=12.8 meV) was performed after the scattering from the Heusler single crystal, used at the same time as the analyzer of neutron polarization $\langle P_A \rangle$0.98). The adiabatic radiofrequency flipper was used for the neutron spin inversion in the whole range of incident neutron energies (the flipping ratio, as determined from the measurements of pure nuclear reflections, was better than 22).

The sample consisted of 2 cm^3 of polycrystalline $La_{1.83}Sr_{0.17}CuO_4$ with T_C=37 K and a transition width of 1.5 K. More detailed information about the sample can be found in /9/.

Antiferromagnetic fluctuations similar to those reported in ref. /6/ for the quantum spin liquid state in pure La_2CuO_4 should result in the diffuse magnetic peak with a maximum position at the momentum transfer $q \approx 1{,}04$ Å^{-1}. We have measured, using mainly the spin-flip mode, a magnetic differential cross-section at T=11 K in the vicinity of the peak expected. The counting time for each point varied from 50 to 100 hours. The nuclear Bragg-reflection 001 was used to reduce the intensities

measured on the cross-section scale. The results of the experiment are shown in fig. /7/. Since no magnetic scattering has been observed we desided to establish the upper limit for the number of magnetic atoms in $La_{1.83}Sr_{0.17}CuO_4$. The procedure described in ref. /8/ allows to estimate this number from the value of its paramagnetic scattering differential cross-section.

The averaging over q of the experimental results shown in fig. gives for the total magnetic scattering cross-section $\sigma_m = -49(26)$ mb/formula unit. Assuming $S=1/2$, $f^2(\vec{q})=0.6$ we estimated the upper limit for the number of Cu atoms carrying spin $S=1/2$. It is less than 2.5% at 11 K. This estimate refers to the energy integration from -28 to 12 meV and 3 standard deviations in σ_m.

Our results show that no magnetic scattering is detectable at the level of $\sigma_m \leqslant 29$ mb/formula unit in superconducting $La_{1.83}Sr_{0.17}CuO_4$ as well as in $YBa_2Cu_3O_7$ /8/. However, a possibility still exists that the range of energy transfers accessible in both experiments is not sensitive to the very fast (10^{-14} s) spin fluctuations corresponding to RVB state[2]. Therefore a similar experiment would be interesting to perform with higher neutron energy transfers and a single crystal.

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