Comparative Study on the Magnetic Excitation Spectra of Y123 and La214 High-T_c Systems - Are the Dynamical Stripes important? -

M. Sato [a,1], M. Ito [a], H. Harashina [a,2], Y. Yasui [a], S. Iikubo [a], A. Kobayashi [a] and K. Kakurai [b]

[a] *Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8602 Japan*
[b] *Advanced Science Research Center, JAERI, Tokai, Ibaraki 319-1195 Japan*

Abstract

The magnetic spectra χ'' of $YBa_2Cu_3O_{6.5}$ are compared with calculated results by the expression $\chi(\boldsymbol{q}, \omega)=\chi^0(\boldsymbol{q}, \omega)/\ \{1+J(\boldsymbol{q})\chi^0(\boldsymbol{q}, \omega)\}$ with $J(\boldsymbol{q})=J(\cos q_x a+\cos q_y a)$. For the proper band parameters and other parameters, we obtained satisfactory agreement between experimental and calculated results without considering dynamical "stripes". The quasi particle broadening has been found to suppress the antiferromagnetic ordering. Effects of the dynamical "stripes" on $\chi''(\boldsymbol{q}, \omega)$ is clearly visible in $La_{2-x}Sr_xCuO_4$, which is in clear contrast to the results of $YBa_2Cu_3O_{6.5}$.

Key words: magnetic excitation; $YBa_2Cu_3O_y$; $La_{2-x}Sr_xCuO_4$; neutron scattering

In the study of high T_c Cu oxides, the detailed wave vector($\boldsymbol{q}$)- and energy(ω)-dependences of the magnetic excitation spectra χ'' present various important information on the physical nature of their strongly correlated electrons. The spectra may also present information on the role of the fluctuating or dynamical "stripes" in the occurrence of the superconductivity. If the fluctuations exist and are slow enough to have significant effects on the electron system, we may have to consider $\chi''(\boldsymbol{q}, \omega)$ essentially in the charge ordered background.

In Fig. 1, data of $\chi''(\boldsymbol{q}, \omega)$ taken for a single crystal of $YBa_2Cu_3O_y$ (Y123 or $YBCO_y$) with y=6.5 ($T_c \simeq$52 K) along (h,h,∼-2) at 7 K are shown, together with fitted curves, at several fixed energy transfers ω, where the resolution convolution is carried out. In the fittings, we used following model, details of which can be found in refs. [1] and [2]. For the susceptibility $\chi(\boldsymbol{q}, \omega)$,

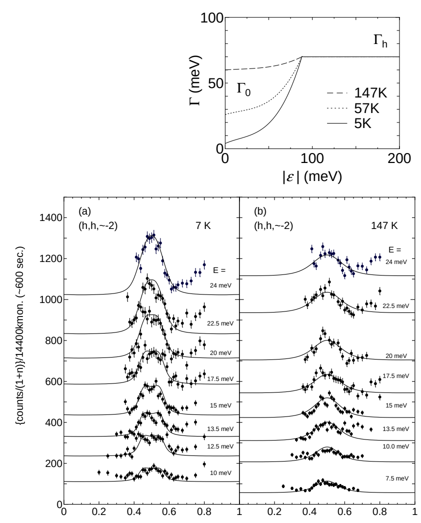

Fig. 1. Bottom figure shows the profiles $\chi''(\boldsymbol{q}, \omega)$ of $YBCO_{6.5}$ at 7 K and 147 K, together with the curves fitted by considering the broadening $\Gamma(\epsilon)$ shown in the top figure. See text for other details.

[1] Corresponding author. E-mail: e43247a@nucc.cc.nagoya-u.ac.jp
[2] Present address. Daido Institute of Technology, Nagoya, Aichi 457-8530

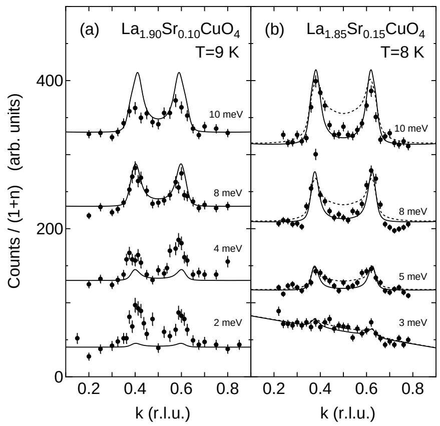

Fig. 2. Data of $\chi''(\boldsymbol{q},\,\omega)$ of $La_{2-x}Sr_xCuO_4$ reported for x=0.10 [4,5] and 0.15 [5] at low temperatures are fitted by a model similar to that used for YBCO. For x=0.1, due to the effect of the softened "stripes", good fitting cannot be obtained. For x=0.15, the effect can be seen as the small value of Γ or Γ_h (See text for details)

the expression $\chi(\boldsymbol{q},\,\omega)\,=\chi^0(\boldsymbol{q},\,\omega)/\{1{+}J(\boldsymbol{q})\chi^0(\boldsymbol{q},\,\omega)\}$ with the exchange coupling $J(\boldsymbol{q}){=}J(\cos q_xa{+}\cos q_ya)$ and the Lindhard function $\chi^0(\boldsymbol{q},\omega)$ of the electron system is used. The $\chi^0(\boldsymbol{q},\,\omega)$ is simply calculated by using the effective band parameters t_0, t_1 and t_2, where we use rather small values of t_0 to introduce the effect of the strong electron correlation (Instead, the intra Coulomb interaction U is set to be zero.). The values of t_1 and t_2 are chosen as -t_0/6 and t_0/5, respectively, to reproduce the Fermi surface shape. The d-wave form of the gap $\Delta_s(\boldsymbol{k}){=}(\Delta_0/2)(\cos k_xa\text{-}\cos k_ya)$ is used, where the absolute amplitudes $2|\Delta_0|$ is assumed to be T-independent (=88 meV), by considering that the gap persists up to very high temperature in the present underdoped system [1,2]. The chemical potential μ has been determined so that the $\boldsymbol{q}$-position of the incommensurate peak of $\chi''(\boldsymbol{q},\,\omega)$ at low temperature T and at relatively low ω agree with those observed for $YBCO_y$. The parameters t_0 and J are correlated and can be chosen with the slight allowance. Here, the curves are for t_0=-30 meV and J=83.5 meV, which are slightly different from those of refs. [1] and [2]. The important point is that the significant broadening $\Gamma(\epsilon)$ of the quasi particle energy which has been experimentally observed [3] has to be introduced in the calculations to reproduce the observed $\boldsymbol{q}$-, ω- and T-dependences of χ'' (See the top figure of Fig. 1. they are the full width at half maximum.). We emphasize here that almost all the observed characteristics of $\chi''(\boldsymbol{q},\omega)$ can be reproduced by the model calculation without considering effects of the dynamical "stripes" [1,2]. Another important point is that not only the gap but also this broadening Γ suppresses the antiferromagnetic ordering.

Similar fittings to the reported data of $La_{2-x}Sr_xCuO_4$ (LSCO or La214) for x=0.10 [4,5] and 0.15 [5] have also been carried out. The solid lines for x=0.10 are for the parameters t_0=-30 meV, t_1= -t_0/6, t_2=0, J=60 meV, $2\Delta_0$=40 meV and Γ=4 meV (ϵ-independent). We cannot obtain a satisfactory fit for any set of the parameters. For x=0.15, the solid lines are for t_0=-40 meV, t_1= -t_0/6, t_2=0, J=60 meV, $2\Delta_0$=30 meV and Γ=4 meV (ϵ-independent) and the broken lines are for different $\Gamma(\epsilon)$ with Γ_0=4 meV and Γ_h=10 meV. The results indicates that we have to use the very small value of Γ_h to obtain the good fittings.

Due to the formation of the fluctuating "stripes", the low energy peak of $\chi''(\boldsymbol{q},\,\omega)$ is significantly enhanced for x=0.10. We have also found that Γ is severely reduced for both LSCO samples as compared with the broadening for YBCO. The large broadening of the quasi particles, which is , we think, one of the characteristics of high-T_c systems [3], to be connected with the RVB-like physical picture, is less significant in LSCO system. It is possibly attributed to the formation of the fluctuating "stripes", even though the band model with the small $\Gamma(\epsilon)$ seems to describe the observed $\chi''(\boldsymbol{q},\,\omega)$ of $La_{1.85}Sr_{0.15}CuO_4$. The presently observed difference between the results of the superconducting samples of LSCO and YBCO indicates that the dynamical "stripes" do not have common effects in high-T_c systems, and do not seem to have a significant role for the occurrence of the superconductivity.

The shift of the incommensurability δ of the peak of $\chi''(\boldsymbol{q},\omega)$ from $\delta\sim$0.10 to $\delta\sim$0.12, recently found to occur in $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$($x$=0.12) along with the appearance of the static "stripes" [6], suggests that δ is rather determined by the Fermi surface shape than by the periodicity of the charge "stripes" in the non-ordered phase. The low T tetragonal structure, which is the characteristic of the La214 system, seems to stabilize the "stripe" phase.

References

[1] M. Sato, M. Ito, H. Harashina, M. Kanada, Y. Yasui, A. Kobayashi and K. Kakurai, J. Phys. Soc. Jpn. **70** (2001) 1342.

[2] M. Ito, H. Harashina, Y. Yasui, M. Kanada, S. Iikubo, M. Sato, A. Kobayashi, K. Kakurai, J. Phys. Soc. Jpn. **71** (2002) 265.

[3] A. V. Puchkov, D. N. Basov and T. Timusk, J. Phys. Condens. Matter **8** (1996) 10049.

[4] H. Kimura, K. Hirota, H. Matsushita, K. Yamada, Y. Endoh, S-H. Lee, C. F. majkrzak, R. Erwin, G. Shirane M. greven, Y. S. Lee, M. A. Kastner and R. J. Birgeneau, Phys. Rev. B **59** (1999) 6517.

[5] C. Lee, K. Yamada, Y. Endoh, G. Shirane, R. J. Biegeneau, M. A. Kastner, M. Greven and Y. J. Kim, J. Phys. Soc. Jpn. **69** (2000) 1170.

[6] M. Ito and M. Sato, unpublished data.