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# The Influence of Spin Fluctuations on the Temperature Dependence of the Magnetic Susceptibility and Nuclear Relaxation in High-Tc Superconductors.

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*Summary.* Mode-mode coupling between uniform and antiferromagnetic spin fluctuations is shown to give rise to a large temperature variation of the normal-phase magnetic susceptibility, Knigth Shift, and $^{17}$O and $^{89}$Y nuclear relaxation as observed in high-Tc superconductors. This mode coupling effect is obtained as a function of temperature and band filling from a semiphenomenological treatement of the loop expansion in the slave-boson formulation of the two-dimensional Hubbard model. Quantitative agreement between theory and experiment is found.

*Introduction.* An important issue of the present extensive study of high-Tc superconductors resides in the determination of the role played by magnetic correlations in the normal phase. $^{63}$Cu nuclear relaxation and inelastic neutron scatterings experiments have recently shown that important antiferrommagnetic spin fluctuations are present above as well as below the superconducting critical point [1]. In contrast, the peculiar temperature variation of the uniform spin susceptibility $\chi(T)$, which also enters in the interpretation of $^{17}$O and $^{89}$Y relaxation rate and Knigth shift data, are at the present time not understood [2]. For YBa2Cu3O6+x with varying x for example, $\chi(T)$ is characterized by a strong temperature dependence for "small" x but which fades out as x approaches unity [2], cocomitant with the depression of antiferromagnetic fluctuations [1], suggesting in turn that uniform and staggered spin fluctuations modes are coupled.

*Results.* We use the spin-rotation invariant slave-boson formulation of the two-dimensional Hubbard model which is known to work for the whole range of interaction and doping [3]. At the loop level for the mode-mode coupling, the dymamic magnetic susceptibility at small q takes a renormalized Fermi-liquid form

$$\chi(\vec{q},\omega)= \chi^*_o(\vec{q},\omega)/[1 + (F^a_o+ \Delta F^a_o)\chi^*_o(\vec{q},\omega)/N(E_F)] \quad . \qquad (1)$$

Where $\chi^*_o(\vec{q},\omega)$ is the bare dynamic susceptibility with a mass renormalization, $N(E_F)$ is the bare density of states, and $F^a_o$ is the Fermi liquid parameter. The renormalization due to the mode-mode coupling effects is contained in $\Delta F^a_o$ which is a function of the interaction, the doping and the spectral weigth of the antiferromagnetic fluctuations. The latter is treated phenomenologicaly by using the successfull antiferromagnetic spectral form proposed by Millis, Monien and Pines [4] in the context of Copper nuclear relaxation. Using their reasonable set of paramaters and equation (1), the results of Figure 1 show the theoretical prediction for $\chi(T)$ vs T (continuous line) at the filling factor $\delta$=.15 together with the experimental measurements (squares) of Takigawa *et al.*[2] obtained for YBa2Cu3O6.63. The agreement betwwen theory and experiment is rather good. Other features of the theory are found to fit the data. Among these, the scaling of the susceptibility to an universal doping curve for both YBaCuO and LaSrCuO families of compounds is remarkably reproduced.

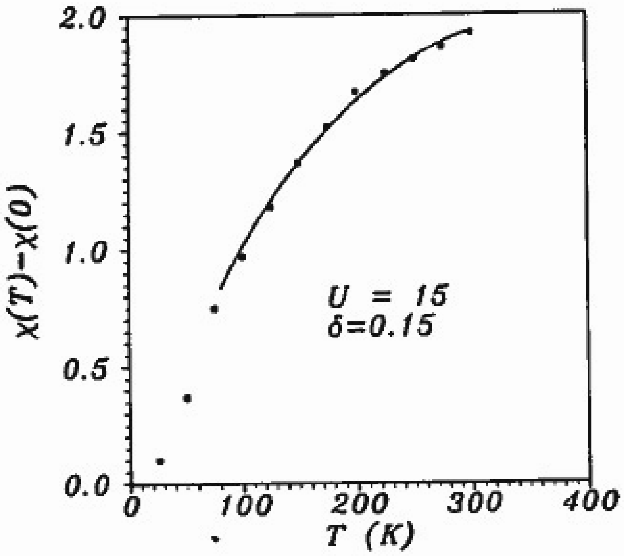


Fig. 1

*Conclusion.* We have shown that a semi-phenomenological treatement of the loop expansion of the slave-boson formulation of the Hubbard model shows that the existence of a mode-mode coupling between uniform and antiferromagnetic spin fluctuations in high-Tc materials can accont quantitatively for the temperature variation of the normal-phase static spin susceptibility. Comparaison between theory and experiments supports the existence of a one-component spin liquid.

## References


[1] a)M. Horvatic *et al.*, Phys. Rev. B39, 7332(1989); C. H. Pennington *et al.*, *ibid.* 39, 274(1989); W. W. Waren, Jr., *et al.*, Phys. Rev. Lett. 62, 1193(1989); b) G. Shirane et al., Phys Rev. Lett., 63, 330(1989); J. M. Traquanda *et al.*, Phys. Rev. Lett. 64, 800(1990); T. Brückel *et al.*, Europhys. Lett. 4, 1189(1987).

[2] M. Takigawa *et al.*, Phys. Rev. B39, 7371(1989); M. Takigawa *et al.*, Phys. Rev. B 43, 247(1991); P. Butaud *et al.*, Physica C 166, 301(1990); Barriquand *et al.*, Physica C, to be published; Y. Yoshinari *et al.*, J. Phys. Soc. Jpn. 59, 3698(1990); H. Alloul *et al.*, Phys. Rev. *Lett.* 63, 1700(1989).; H. Alloul *et al.*, in Proceedings of the Symposium on High-Tc superconductor Materials of the EMRS spring meeting, Strasbourg, France (1990).

[3] T. Li *et al.*, Phys. Rev. B40, 6817(1989); P. Wölfle and T. Li, Z. Phys. B78, 45(1990).

[4] A. J. Millis, H. Monien and D. Pines, Phys. Rev. B41, 1797(1990).