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Have we known the mechanisms of High Temperature Superconductivity for a long time ?

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Abstract: Among the many possible mechanisms suggested for high temperature superconductivity in solid state materials in the past 30 years some are emerging as the likely candidates for the cuprate superconductors discovered in the last few years. Highlights of these models are presented in this paper.

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1. Introduction

The discovery of superconductivity at high temperatures (~100K) in oxide materials (mainly cuprates) has thrown serious challenge to theorists regarding the mechanisms that may be operative in these rather strange systems[1]. The pace of research activity all over the world has been frenetic and thousands of papers (both experimental and theoretical) have been published since 1986. In the present paper, we shall be concerned about the mechanisms that appear feasible in the face of the current experimental results[2,3]. Several models involve the revival of old theories which have been put forward by theorists in the last thirty years[4] However, we shall be selective in our choice. This is particularly important in view of the anomalous normal state properties of these system. Thus the mechanism must be capable of explaining this strange behaviour. This arises from the deviations from he usual fermi liquid behaviour of these systems. As the systems are very close to the metal-insulator transition, the degree of doping determines the insulating (also magnetic) and metallic phases. This points to the conclusion that the relevant parameters (e.g. U,t,J etc) are drastically renormalised with doping.

2. Ceramic superconductors : some relevant properties

Before discussing the various models suggested for the high T_c oxide materials, it is desirable to have a brief account of some crucial physical properties.

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2.1. Some properties of cuprates :

The structural properties of these new systems are as follows :

(a) (214 system) $La_{2-x}M_xCuO_4$ (with M = Ba, Sr, Ca) has K_2NiF_4 structure with an orthorhombic distortion.

(b) (123 system) $LnBa_2Cu_2O_{6+x}$ ($x \sim 0.95$, Ln = Y, La, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, Yb) has orthorhombic structure.

(c) $Bi(CaSr)_{n-1}Cu_nO_{2n+4}$ (n=1, 2, 3) again has orthorhombic structure.

(d) $Tl_2Ca_{n-1}Ba_2Cu_nO_{2n+4}$ (with n = 1, 2, 3, 4) has primitive tetragonal.

All these systems share some common structural features in the sense they have defect perovskite layers.These cuprates have two-dimensional CuO_2 planes (*c*-layers) which are the conducting sheets and are responsible for anisotropic electrical and magnetic properties. The CuO_2 layers are placed in an environment[4,5] of $M_n{}^PO_m$ (*P*-layers) with M = Cu, Bi, Tl. These sandwiches comprising $CuO_2M_n{}^PO_m$ layers are in turn separated by insulating (I) layers of rare earth or Ca etc. In $La_{2-x}M_xCuO_4$ (214) system, however, the *P*-layer is absent. The copper-oxygen bonds in the sheets are covalent with distance of the order of 1.9A and coordination four.

The 214 and 123 systems show extremely different properties as a function of doping or oxygen content[6]. Thus $La_{2-x}M_xCuO_4$ with $x = 0$ is an insulator with antiferomagnetic (AF) order of the copper spins (magntic moment ~ 0.45 μ_B per copper ion) below the Nee'l temperature T_N (250K). On doping (excess oxygen or addition of Ca, Sr, or Ba, $x \neq 0$) the long range AF order is destroyed along with the appearance of the metallic state which goes to superconducting phase below T_c. The amazing aspect is that even a small doping destroys long range magnetic order with a moment reducing rapidly with hole concentration. The $YBa_2Cu_3O_{6+x}$ system, in the range of oxygen content $x = 0$ to 0.4, has tetragonal structure and is insulating with long-range AF order with T_N decreasing from 450K (for $x = 0$) with increasing oxygen content and vanishing at about $x = 0.4$. When the oxygen is in the range $x = 0.5$ to 1.00, the system is metallic, the structure orthorhombic and it becomes superconducting below a critical temperature T_c which increases with x upto a maximum value and then declines.

In both the systems,[7,8] there is experimental evidence of the species Cu^{1+},Cu^{1+} –O – O^-,O_2^{2-} etc in the superconducting (SC) phase in addition to Cu^{2+}, O^{2-}, O^-. Further, in the SC phase there is no evidence now of Cu^{2+} with local moments as it is EPR silent[9]. Further, NMR and nuclear quadrupole moment data suggest that fluctuating charges involve 1+ and 3+ on copper and 1– on oxygen sites[10]. The relevant experimental results for the HTSC can be summarized as follows[3]:

(a) Various measurements, including Josephson tunnel junction, flux quantization, Shapiro-steps and vortex lattice image imply that the electric charge carriers form pairs below T_c.

(b) The reported measurements of the superconducting energy gap, namely, $2\Delta/K_BT_c$ show it to lie in the range 2 to 20 with the values converging towards 8.

(c) The oxygen isotope effect in HTSC is very small and those for copper, barium, and other rare-earth atoms vanishingly small. These point towards a very limited involvement of the phonon mediated mechanism.

(d) The coherence ξ length is rather small and highly anisotropic. Thus ξ_c along *c*-direction is around 5A and ξ_{ab} in the *ab* plane about 15-35 A. Similarly, the upper critical field H_{c_2} is also highly anisotropic. The pairing is of *s*-wave (singlet) type and type II behaviour in a magnetic field. To sum up, the high T_c value, short coherence length, low density of states N(o), low carrier concentration $n = 10^{21}/cm^3$, large structural, electrical and magnetic anisotropics are the characteristics of HTSC compared to conventional low-T_c superconductors. Many of the normal state properties are full of surprises and differ from the conventional metals describable by a Fermi-liquid model. As noted by Varma[11], the electrical resistivity $\rho(T)$, the thermal conductivity $K(T)$, the optical conductivity $\sigma(\omega)$, Raman scattering intensity $S(\omega)$, tunneling conductance as a function of voltage $g(V)$, the nuclear relaxation rate $T_1^{-1}(T)$ and the Hall coefficient $R_H(T)$ all show anomalous behaviour. In order to explain all these aznomalies, Varma and coworkers[11] have put forward the hypothesis of marginal Fermi liquid and suggested the phenomenological magic polarizability involving some unknown spin and charge density excitations. It has the form

$$\text{Im}\,\tilde{P}\,(q,\omega) = -N(o)\,\frac{\omega}{T} \text{ for } |\omega| < T \text{ and } \sim N(o)\,\text{sign}\,\omega \text{ for } \omega_c > T \qquad (2.1)$$

where ω_c is a cut-off frequency. Later we shall see that this polarizability can be derived from a microscopic electronic mechanism which was suggested by us a long time ago for the enhancement of T_c in some superconductors and has been invoked by us and other workers for HTSC[3].

However, before considering this mechanism, we shall present the highlights of some other models that have been suggested for cuprate superconductors. The French school (Labbe and Bok 1987, Friedel 1989)[14,15] has made a strong case for the phonon mechanism by stressing the quasi-2D character of these layered oxides. According to them the maximum value of T_c occurs when the Fermi level sits on the van Hove singularity. Their result for the in plane situation is

$$K_B T_c(p) = 2t_p \exp\left(-\frac{\sqrt{\pi_p}}{V_p}\right), \sqrt{\lambda} = \frac{\sqrt{\pi_p}}{V_p} \qquad (2.2)$$

where t_p is the intraplane transfer integral and V_p is the phononinduced BCS type electron-electron interaction. The above is for a weak coupling situation. Note that a small $\lambda = 0.1$, but with t_p = 1eV, gives $T_c \sim$ 100K. The higher value of T_c comes because the pre-exponential factor $K_B\theta_D$ is replaced by an electronic energy t_p as the appropriate cut off is provided by the fast fall of the wings of the van Hove anomaly. This may explain both high T_c and very weak isotope effect. But so far there is no clear indication that the Fermi level lies near the logarithmic singularity in these cuprate superconductors.

3. Model mechanisms

The above results, particularly those connected with isotope effect, suggest that the conventional phonon-mediated pairing mechanism will give only a limited contribution in these high T_c systems. The mechanisms which are of electronic origin can be classified under two broad categories. One type of models is guided by the belief that superconductivity in cuprates is of magnetic origin. This is motivated by the fact that pure '214' and '123' (ie. $x = 0$) compounds are antiferromagnetic insulators. There are many variants of the magnetic mechanism (for example, RVB, t - J model, spin-bag, flux phases etc)[3].

The other type of mechanisms involves the exchange of electronic excitations (e.g. charge transfer, excitons, plasmons, charged bosons, biexcitons etc) arising from charge fluctuations in the system. In what follows, we present the highlights of a few models that seem plausible along with our comments.

(a) Mechanism based on magnetic interactions :

Anderson hypothesized that the ground state for pure La_2CuO_4 is the so called Resonating Valence Bond (RVB) or quantum spin liquid state[16]. This is described as a state in which spin singlet configurations of all possible pairs of Cu^{2+} ions (supposed to be in spin 1/2 state) are superposed.

The quasiparticle excitations that can be generated over the RVB ground state are envisaged to be of two kind. The 'spinon' which is just an isolated unpaired spin. It does not carry a charge, for example Cu^{2+}. These spinons can propagate freely through the copper lattice. Being spin-half objects (hence fermions) and subject to the exclusion principle their distribution in the lowest energy states describes a psuedo-Fermi energy.

The other type of excitation is a single spinless charge on copper site. It is called "holon" and is produced by the process Cu^{2+}_{σ} + hole$_{-\sigma} \rightarrow Cu^{3+}_{\uparrow\downarrow}$. Here Cu^{3+} is not in the spin triplet state owing to crystal field energy splitting. Further, the holons being in spin zero state are bosons. In this model , superconductivity is thought to arise from the Bose condensation of holons in doped materials ($x > 0$).

The RVB state represents a quantum spin fluid in two dimensional planes of CuO_2. The separation of charge and spin visualized in the model has not been universally accepted. The Josephson tunnelling on the new superconductors shows the presence of charge-2 units which is consistent with BCS pairing rather than Bose condensation of holons which would produce charge-1 order parameter. To overcome this criticism, the later versions of the theory stipulate that at T_c holons condense owing to cooperative Josephson tunnelling[10].

However, there are several theoretical and experimental results which are difficult to reconcile with RVB predictions. The fact that pure '214' and '123' (with $x = 0$) systems are antiferromagnetically ordered encouraged many workers to invoke the spin fluctuation exchange mechanism for superconductivity based on the one band Hubbard model[10].

But the recent analyses of many kinds of experimental results point against the magnetic origin of superconductivity[17]. In fact magnetic interactions are competing against rather than supporting it. Important points to note is that doping strongly reduces the effective intralayer exchange coupling between copper ions and the effective moment for site

and the appearance of Pauli susceptibility and hence the Fermi liquid with increase in hole concentration[17].

Obviously the relevant parameters (U, t, J etc.) are drastically renormalised with doping.

(b) Mechanism based on charge fluctuation exchange :

Theorists have invoked various kinds of electronic polarization modes in the pairing mechanism, under equilibrium or non-equilibrium conditions, for a long time for achieving high temperature superconductivity (for example models by Little[18], Ginzburg[19], GUS[12], US[13], Kumar and Sinha[20] etc). Among the modes involving charge fluctuations, long-wavelength charge excitations were immediately invoked for inducing attractive interaction after the discovery of cuprate superconductors by several workers[10]. These high T_c systems can sustain numerous planar (dispersion $\omega \sim \sqrt{q}$) and acoustical ($\omega \sim q$) plasmon modes. However, a recent analysis by Mahan and Wu[21] shows that long-wavelength plasmon modes cannot produce attractive pairing interaction in these materials. This negative conclusion is applicable to both interlayer and intralayer s-wave pairing.

Short wavelength charge transfer modes, in the context of high T_c cuprates, were first invoked by Jagadish and Sinha[22] and Varma *et al*[23]. In the formulation of the former authors, charge transfer is visualized to take place from doubly occupied states below the Fermi level to the quasilocalized states above it along with scattering of carriers.

These manifolds may belong to the non-bonding or weakly bonding states of copper and oxygen. The states above the Fermi level may be generated by doping or defects. There is experimental support to such[10] states.

Varma *et al*[23] use an atomistic description and envisage the excitonic transition of the type $Cu^{3+}\ O^{2-} \rightarrow Cu^{2+}\ O$. Bishop *et al*[5] have reemphasized this mechanism and claim that these processes provide the 'pump' which drives the pairing in CuO_2 conducting layers. The possibility of interlayer pairing through such charge transfer exists.

However, there are some constraints on the excitonic mechanism. In this, electron-hole excitation occurs within narrow two-band system in addition to the conducting carrier band. The intermediate excited states of the electron-hole pair involve one singlet and three triplets. While the contribution of the singlet is attractive that of triplets is repulsive. Thus unless there is an additional mechanism that produces strong splitting of intermediate electron-hole singlet and triplet states exciton mechanism may not lead to pairing.

Accordingly, one has to look for electronic mechanisms which do not face the above constraint. We consider this next.

4. Lochon-Fermion model

Keeping in view the anomalous normal state properties of the systems, the correct mechanism should have features of a material which lies close to metal-insulator transition. The mechanism which we develop in this section involves pairwise localization and delocalization of fermion in the system and is responsible for the anomalous behaviour and also furnishes the effective interaction for pairing in the s-wave channel. The fact that certain kinds of chemical species are present in the cuprates, renders the mechanism important and effective. For the stabilization of real space singlet pairs, this interaction

mechanism was invoked by the author three decades ago[24]. In the context of the enhancement of T_c of some superconductors, which contain impurities centres which can harbour real space singlet pairs (in effect composite local charged bosons), this was extended by GUS[12] and US[13] in the mid sixties. In some sense, such centres anticipate singlet bipolarons (both onsite and intersite) which became more fasionable from mid seventies[25]. It was implicit in our earlier work, that the stabilization of such singlet pairs (lochons-local charge bosons) can arise both from lattice and electronic polarizations-negative $U(E)$ centres[12].

For high temperature oxide superconductors this mechanism involving lochons has been invoked by us[26-29] and several other groups in many different forms[30-34]. We can describe the mechanism, in atomistic or molecular language by the following[26-29]. There is correlated charge transfer from the species $X^{\uparrow\downarrow}$ (either a molecular complex or ionic species such as Cu^{1+}, O^{2}, O_2^{2} Bi^{3+}, Tl^{1+} etc.) to holes in the system (Cu^{2+}, O etc). In the process $X^{\uparrow\downarrow}$ changes to X^{o}. As the spin remains zero in both $X^{\uparrow\downarrow}$ and X^{o}, the boson character of the excitation is maintained. The two states constitute a two level Bose system. Symbolically, the process may be represented as

$$Y^{\uparrow} - X^{\uparrow\downarrow} - Y^{\downarrow} \underset{\leftarrow}{\rightarrow} Y^{\uparrow\downarrow} - X^{o} - Y^{\uparrow\downarrow}$$

where Y^{σ} is the seat of a hole (eg. O^{-}, Cu^{2+}, etc).

For actual calculation, we have to recast the mechanism in the field theoretic language. The relevant Hamiltonian can be written as[12,28]

$$H = H_0 + H_{cl} \tag{4.1}$$

where

$$H_o = \sum E_{\underline{k}} a^{+}_{\underline{k}\sigma} a_{\underline{k}\sigma} + \sum \hbar\omega_l b^{+}_l b_l \tag{4.2}$$

The first term of (4.2) is the single particle energy of the carriers (e.g. holes) with $a^{+}_{\underline{k}\sigma}$, $a_{\underline{k}\sigma}$ denoting their creation, annihilation operators in the state $|\ \underline{k}\sigma >$, $\underline{k}$ = wave vector and σ the spin index. The hole states are appropriate band states derived from copper and oxygen orbitals of the CuO_2 conducting sheets. The second term of (4.2) is the Hamiltonian for the lochons with energy $\hbar\omega_l$ given by

$$\hbar\omega_l = E_l(X^{o}, Q_l) - E_l(X_l^{\uparrow\downarrow}, O_l^{o}) \tag{4.3}$$

The configuration of the surrounding atoms is collectively denoted by Q_l, Q^{o}_l. The lochons are composite objects with their creation, annihilation operators related to local fermion operators i,e.

$$b_l^{+} = C^{+}_{l\downarrow} C^{+}_{l\downarrow}, \quad b_l = C_{l\downarrow} C_{l\uparrow} \tag{4.4}$$

and involve the creation and anhilation of a pair of fermions in the singlet state at the same site (complex) l. The new interaction between carriers and lochons (local charged bosons) is given by

$$H_{cl} = \sum g_1 \left(a^{+}_{\underline{k}\uparrow} a^{+}_{\underline{k}'\downarrow} b_l + a_{\underline{k}'\downarrow} a_{\underline{k}\uparrow} b^{+}_{l} \right) \delta(\underline{k} + \underline{k}') \tag{4.5}$$

where the carrier-lochon interaction is generated by g_1, being the matrix element of the effective two-body potential. In order to carry out a proper field theoretic treatment it is convenient to go over to the Nambu formalism[35] In this the carrier energies become $\sum E_{\underline{k}} \psi^{+}_{\underline{k}} \sigma_z \psi_{\underline{k}}$ and the interaction term (4.5) as

$$H_{cl} = \sum_{\underline{k}\, l} \psi^{+}_{\underline{k}} \left[g_1 \sigma_+ b_1 + g_l \sigma_- b^{+}_{l} \right] \psi_{\underline{k}}, \tag{4.6}$$

$$\psi_{\underline{k}} = \begin{pmatrix} a_{\underline{k}\uparrow} \\ a^{+}_{\underline{k}\downarrow} \end{pmatrix} \text{ and } \psi^{+}_{\underline{k}} = \left(a^{+}_{\underline{k}\uparrow} \;\; a_{\neg \underline{k}\downarrow} \right) \tag{4.7}$$

$\sigma_{\pm} = \frac{1}{2} \left(\sigma_x \pm i\sigma_y \right)$, $\sigma_{x,y,z}$ are the Paulimatrices. It is also useful to define

$$P_{\pm} = \frac{1}{2} \left(1 \pm \sigma_z \right) \tag{4.8}$$

First, we calculate the lochon self-energy which, in effect, gives the polarizability for the relevant charge excitation. In this Matsubara representation we have[37]

$$\tilde{P}\,(i\omega_l) = \beta^{-1} \sum_{\underline{k}, \omega_n} |g_1|^2 T_r \left(\tilde{G} \left(\underline{k}_{-1} i\omega_n \right) \sigma_+ \tilde{G} \left(\underline{k} \; ; i\omega_n - i\omega_l \right) \sigma_- \right)$$

where $\omega_l = \dfrac{2n\pi}{\beta}$ and $\omega_n = \dfrac{(2n+1)\pi}{\beta}$, $\beta = \left(\dfrac{1}{k_B T} \right)$ (4.9)

are the Matsubara frequencies for lochons and the fermions respectively. Here $\tilde{G} \left(\underline{k} \; ; i\omega_n \right)$ are the fermion temperature green's functions. Using a free hole propagator $(i\omega \pm \epsilon_k)^{-1}$, one easily gets after frequency summation (integration)

$$\tilde{P}\,(i\omega_l) = \sum_{k} |g_l|^2 \; \frac{\tanh \dfrac{\beta\varepsilon_k}{2}}{i\omega_l - 2\varepsilon_k}$$

or

$$\tilde{P}\,(\omega) = \int \frac{|g_l|^2 N(\varepsilon) \tanh \left(\dfrac{\beta\varepsilon}{2} \right)}{\omega - 2\varepsilon + i\delta} \, d\varepsilon. \tag{4.10}$$

Thus we get[37]

$$\text{Im } \tilde{P}(\omega) = -\frac{\pi}{2}\left|g_1\right|^2 N(O) \tanh \frac{\beta\omega}{4} \tag{4.11}$$

It is easy to see that, to leading order,

$$\text{Im } \tilde{P}(\omega)\alpha - N(0)\frac{\omega}{T} \quad \text{for } |\omega| < T$$

and $$\alpha - N(0) \text{ sign } \omega \quad \text{for } |\omega_c| > T \tag{4.12}$$

which is the form of the magic polarizability required in the phenomenological hypothesis of Varma[11]. The interaction mechanism (4.5) involves a mixture of fermions and their pair resonances (lochons)—which has been anticipated by us over three decades ago[12,24]. As the magic polarizability can explain all the anomalous normal state properties of the cuprates, the mechanism which leads to it is of utmost importance in describing both the normal and superconducting properties of these materials. The process is fully consistent with the nature of the materials i.e., closeness to metal insulator transition.

That the interaction H_{el} gives BCS pairing of the s-wave type is easily derived ; one gets

$$H_{int} = -\sum \frac{\left|g_1\right|^2}{\hbar\omega_l} a^{+}_{k'\uparrow} a^{+}_{-k'\downarrow} a_{-\underline{k}\downarrow} a_{\underline{k}\uparrow} \tag{4.13}$$

The above interaction is attractive for the entire conducting band and hence the transition temperature can be high.

An important feature of the interaction (4.5) is that the numbers of lochons (N_l) fermion (N_f) pairs are not independently conserved but the total number of particles is conserved. Owing to this constraint, the strength of the pairing interaction is modulated by the factor $f(\zeta_h) = \zeta_h (1 - \zeta_h)$ where ζ_h is the hole concentration.

In the weak coupling situation, the gap function is given by

$$\Delta_\omega = 2 W_{el} \exp\left[-\left(f(\zeta_h)\lambda_{el}\right)^{-1}\right] \tag{4.14}$$

where $\lambda_{el} = \left(\langle g^2 \rangle / \hbar\omega_l\right) N(0)$ and W_{el} is the electronic cutoff energy. The expression for the critical temperature when both the phononic and lochonic mechanisms are operative has been given in a series of papers[26-29]. An important result to be noted is that, owing to the presence of the modulating factor $f(\zeta_h)$, the transition temperature will rise with the carrier (hole) concentration, attain a maximum and then decline. This kind of behaviour has been experimentally seen in most of the cuprates. Of course, experiment cannot always span the entire region, ie. from $\zeta_h = 0$ to $\zeta_h = 1$.

A few words about the strong coupling calculation will be in order here. Experiment so far has not produced unambiguous result indicating clearly whether or not the systems are strong or weak coupling superconductors. When $\hbar\omega_l$ is close (but above) the fermi level, i.e., $\omega_l \to 0+$, one must consider the strong coupling situation. Owing to lattice displacements as well as renormalization effects arising from doping[4,35], (note $\hbar\omega_l$ involves U also), we have

$$\hbar\omega_r = \hbar\omega_l - \sum \frac{|\vartheta_q|^2}{\hbar\omega_q} - \frac{p\,|g_L|^2}{E_F} \tag{4.15}$$

where ϑ_q is the hole-phonon coupling constant, ω_q intramolecular vibration frequency, E_F Fermi energy $p = E_F N(0)$ is the number of holes per unit cell. The strong coupling calculation has been done by serveral workers including us[4,35] We shall quote the relevant result. The critical temperature for a system harbouring lochon sites turns out to be

$$T_c \simeq \frac{|g_l|^2}{\hbar\omega_r}\, p\,(1-p), \tag{4.16}$$

as this depends not only on hole density in the system but also the density of lochon centres per unit cell. The strong coupling result will also display the same behaviour of the dependence of T_c on p as noted earlier. Here T_c is dependent on the lochon mass $m_l \propto \Lambda^{-1}$ with $\Lambda \equiv \frac{|g_l|^2}{\hbar\omega_r}$. It is clear that for large values of Λ, the critical temperature is not bounded exponentially as in the weak coupling BCS type case[35]

In a similar boson-fermion model the authors[33] find a critical density above which both bosons and fermions are superfluid analogous to the BCS type case. Another, formulation of the model is to consider two band situation[32] One is a wide band (WB) of fermions (spin 1/2) and the second is a very narrow band (1) of bosons (spin 0) being composities of local fermion pairs. A charge exchange between these two leads to the interaction given in (4.5).

For energy of local pairs lying above the Fermi level, one gets BCS type behaviour. The maximum T_c is obtained when the carrier density distribution is such that n (WB) = $n(1)$. The behaviour is similar to the lochon model.

Thus the researchers of various groups point to the role of pairwise creation, annihilation of fermions via resonance boson (lochons) states as the dominant mechanism of the high T_c system.

There are other variants of double charge fluctuations also, for example pairing through exchange of biexcitons[36] The correlated charge fluctuation mechanisms (involving lochons or biexcitons) can lead to both intralayer and interlayer pairing but always in the *s*-wave channel. This depends on the presence of appropriate complex, $Y^{\sigma} - X^{1\downarrow} - Y^{\sigma}$ (e.g. $O^- - Cu^{1+} - O^-$) in the conducting sheets and in the *c*-directions.

The advantage of these mechanisms is that they work in unison with the phonon-mediated pairing process.

5. Concluding remarks

In the foregoing sections, we have presented an overview of some of the properties of cuprate superconductors. We have seen that even the normal state properties are puzzling ; the systems in the metallic phase deviate from a Fermi liquid behaviour. The reason is that unlike conventional metals, the number of carriers is not fixed. The magic polarizability introduced phenomenologically for explaining the anomalous properties of the normal state

can be drived on the basis of fermion-lochon interaction. This vintage interaction[12,24] which was suggested by us in early sixties leads not only to the magic polarizability but gives the BCS type pairing in the s-wave channel. Several other groups elsewhere also are converging to similar ideas[25]

The pairing interaction has been discussed here for both the weak and strong coupling situations. We believe that the correlated charge fluctuation mechanism, is the dominant mechanism in these cuprates and, in unison with phonon mechanism, can account for high T_c and other properties. The antiferromagnetic spin correlations in the system does not conflict with the lochon-fermion interaction. Indeed experimental data favour high energy charge fluctuation mechanism.

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