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CORRELATED FERMIONS AND TRANSPORT IN MESOSCOPIC SYSTEMS

edited by

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XVIth Moriond Workshop on :

Correlated Fermions and Transport in Mesoscopic Systems

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96' RENCONTRES DE MORIOND

The XXXIst Rencontres de Moriond were held in 1996 in Les Arcs 1800, Savoie, France.

The first meeting took place at Moriond in the French Alps in 1966. There, experimental as well as theoretical physicists not only shared their scientific preoccupations but also the household chores. The participants in the first meeting were mainly French physicists interested in electromagnetic interactions. In the following years, a session on high energy strong interactions was also added.

The main purpose of these meetings is to discuss recent developments in contemporary physics and also to promote effective collaboration between experimentalists and theorists in the field of elementary particle physics. By bringing together a relatively small number of participants, the meeting helps to develop better human relations as well as a more thorough and detailed discussion of the contributions.

This concern of research and experimentation of new channels of communication and dialogue which from the start animated the Moriond meetings, inspired us to organize a simultaneous meeting of biologists on Cell Differenciation (1970) and to create the Moriond Astrophysics Meeting (1981). In the same spirit, we have started a new series on Condensed Matter Physics in January 1994. Common meetings between biologists, astrophysicists, condensed matter physicists and high energy physicists are organized to study the implications of the advances from one field into the others. I hope that these conferences and lively discussions may give birth to new analytical methods or new mathematical languages.

At the XXXIst Rencontres de Moriond in 1996, four physics sessions, one astrophysics session and one biology session were held :

* January 20-27	"Dark matter in cosmology, Quantum measurements and Experimental gravitation.
	"Correlated fermions and transport in mesoscopic systems"
* March 16-23	"Electroweak Interactions and Unified Theories"
	"Microwave background Anisotropies"
* March 23-30	"QCD and High Energy Hadronic Interactions"
	" Rencontre de Biologie - Méribel "

longtemps à l'étude des corrélations électroniques (la bosonisation a été inventée il y a plus de trente ans), l'étude des interactions dans le transport quantique mésoscopique peut s'avérer encore plus complexe. Du point de vue expérimental, les interactions ont toujours été présentes: il n'est pas possible de les faire disparaître. Dans certains cas, une description en termes de quasi-particules est satisfaisante pour interpréter l'expérience. La recherche des effets des interactions dans les systèmes de dimension réduite, tels que les conducteurs organiques ou les fils quantiques, a tenté d'isoler un comportement qui ne peut pas être expliqué par une description en termes de quasi-particules.

Il nous est donc apparu propice de rassembler la "communauté mésoscopique" et la "communauté des électrons corrélés" dans le cadre de cette conférence, et d'ouvrir un dialogue sur plusieurs sujets d'intérêt commun. La première rencontre de Moriond de matière condensée intitulée "Effets coulombiens et ondulatoires dans les petites structures électroniques", avait déjà abordé certains sujets figurant dans cet ouvrage: les jonctions métal normal-supraconducteur, les effets de charge dans les boîtes quantiques, les systèmes désordonnés, par exemple. Ces sujets ont évolué rapidement, et les résultats présentés ici reflètent les progrès des deux dernières années tant du point de vue théorique que du point de vue expérimental. D'autres sujets, liés aux corrélations électroniques, comme les liquides de Luttinger, la délocalisation en présence d'interactions, l'effet Hall quantique fractionnaire, (en particulier la physique des états de bord et du niveau de Landau demi-rempli), représentent des directions nouvelles de la physique mésoscopique. Dans une certaine mesure, ces pôles d'intérêt sont apparus parce que les chercheurs ont utilisé l'expertise de domaines voisins pour l'appliquer à la physique mésoscopique. Finalement, il faut admettre l'importance donnée à la théorie dans cette conférence, ce qui traduit l'importance donnée au mots "fermions corrélés" figurant dans le titre de ce livre. Nous espérons que cette conférence et la publication de ses actes permettront une meilleure appréhension des problèmes liés aux corrélations dans les systèmes mésoscopiques et apporteront une certaine unification entre leurs différents aspects.

Thierry Martin et Gilles Montambaux

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'96 Rencontres de Moriond

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CORRELATED FERMIONS IN 1D AND QUASI-1D

ADIABATIC DESTRUCTION OF ANDERSON LOCALIZATION

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We study the diffusive wave spreading in a 1-d Anderson model due to a slow parameter variation with a frequency ω. The diffusion rate depends on frequency as $D \propto \omega^{\alpha}$. A theoretical approach based on Mott's mechanism of energy absorption gives $\alpha = 2/3$ in agreement with numerical data.

In this paper we study the behaviour of 1-d Anderson model under a slow variation in time of an external a.c. field. This model represents the problem of non interacting electrons in a disordered medium. One of its characteristics is the possibility to have an energy absorption which gives rise to a finite σ_{ac}. For localized state the dependence of σ_{ac} on the small frequency can be obtained from Mott's law[1] and it gives $\sigma \propto \omega^2$. Nevertheless the time variation of the field can also lead to a destruction of localization along the chain with a consequent electron diffusion. It is not obvious how these two kinds of diffusion are related,in spite of the fact that in literature different results can be found[2,3] in different contexts. Indeed numerical results[2] showed a dependence $D \sim \omega^{\alpha}$ (with $\alpha = 0.6$) of the diffusion rate along the lattice with the small frequency of the external field, even if the theoretical considerations given there were not able to derive α. Another theoretical investigation[3] gives $\alpha = 1$ and this contradiction stimulated our research on this phenomenon. We investigated the destruction of Anderson localization in a 1-d random chain with modulated hopping elements :

$$i\dot{\psi}_n = E_n\psi_n + V[1 + \epsilon(\sin\omega_1 t + \sin\omega_2 t)](\psi_{n+1} + \psi_{n-1}) \qquad (1)$$

where E_n are randomly distributed energies in $[-W, W]$ and ω_1, ω_2 are two incommensurate frequencies. For $E = 0$ all eigenstates are exponentially localized with a localization length $\ell \sim 25(V/W)^2$ in the middle of the band. This problem can be mapped to a 2-d problem in which after an exponentially large time t^*, 2-d localization takes place with $\ell_2 \sim e^{\ell}$. For $t < t^*$ wave packets spread diffusively on the lattice with $D = \Delta n^2/t$. As in Mott's picture the electron absorb energy with a diffusion rate $D_E \sim (\Delta E)^2/t$. Due to the dispersion rule $E = 2V\cos p$ this leads to a momentum spreading $\Delta p \sim \Delta E/V \sim \sqrt{D_E t}/V$. The width of the spreading along the lattice will be given by $\Delta n \sim V\Delta p\, t \sim \sqrt{D_E t}\, t$. This spreading will be coherent up to the time t_c which can be estimated from $\Delta n \sim \ell \sim \sqrt{D_E}\, t_C^{3/2}$ and that gives $t_c \sim \ell^{2/3} D_E^{-1/3}$. After this time the coherence is destroyed and quantum transitions between localized states take place. Since the size of one jump is ℓ and the transition time is t_c, the diffusion rate can be estimated as $D \sim \ell^2/t_c \sim \ell^{4/3} D_E^{1/3}$. We can estimate D_E using the Mott law $D_E \sim \omega^2\Gamma$ where Γ (the transition rate) is given by the golden rule $\Gamma \sim F^2\rho$, $F \sim \epsilon V$ being the matrix element for one photon transition and $\rho \sim \ell/V$ the density of states. Then one has the following estimate: $D_E \sim \omega^2\Gamma \sim \omega^2 F^2\rho \sim \omega^2\epsilon^2\ell V$ and then $D \sim \ell^{4/3} D_E^{1/3} \sim \ell^{4/3}(\omega\epsilon)^{2/3}\ell^{1/3}V^{1/3}$ or

$$D/\ell \sim (\epsilon\omega\ell\sqrt{V})^{2/3} \qquad (2)$$

which is the relation we have tested numerically. The above estimate holds if $t_c > 1/\Gamma$ that

means $\epsilon > \sqrt{\omega/V}/\ell$. Moreover we require to be in the perturbative regime $\Gamma\rho > 1$ which in turn implies $\epsilon > 1/\ell$. The prediction (2) has been been tested in numerical simulation of the model (1). Results are presented in Fig.1. The theoretical line is in good agreement with the best fit procedure which gives $\alpha = 0.74(3)$ instead of 2/3. This can be justified with the effect of quantum correlations[4].

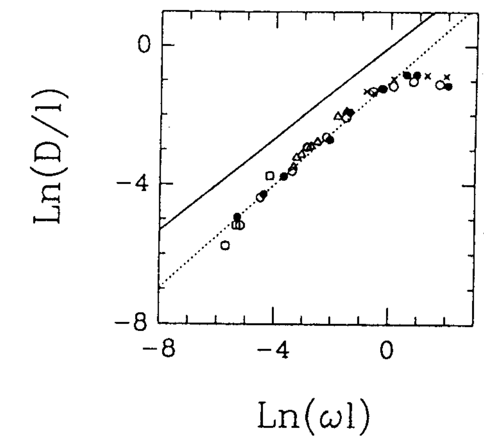

*FIG.*1 Diffusion rate D as a function of the rescaled variables with $V = 1$, $\epsilon = 0.5$, $\ell = 25(V/W)^2$, $\omega_1/\omega_2 = 1.618...$, and $E = 0$. Symbols are : open circles ($W = 1.5$), full circles ($W = 1$), crosses ($\omega_1 = 0.07$), triangles ($\omega_1 = 0.005$), squares ($\omega_1 = 0.0003$). Dashed line is the best fit while full line is the theoretical prediction $\alpha = 2/3$.

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DESTRUCTION ADIABATIQUE DE LA LOCALISATION D'ANDERSON

Nous étudions l'onde diffusive qui se dévelope dans le modelè d'Anderson à une dimension, à la suite d'une lente variation, de fréquence ω. Le taux de diffusion dépend de la fréquence, à travers une loi de puissance $D \propto \omega^{\alpha}$. Une approche théorique, basée sur le méchanism d'absorption d'énergie de Mott, donne le résultat $\alpha = 2/3$, en accord avec les données numériques.