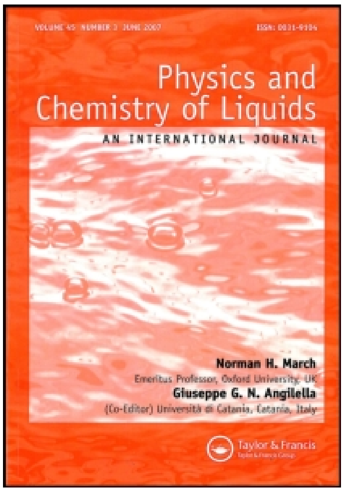

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Magnetic Susceptibility of Strongly Correlated Expanded Liquid Cs related to Electrical Resistivity near Criticality

N. H. March[a]
[a] Theoretical Chemistry Department, University of Oxford, Oxford, England

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LETTER
Magnetic Susceptibility of Strongly Correlated Expanded Liquid Cs related to Electrical Resistivity near Criticality

N. H. MARCH

Theoretical Chemistry Department, University of Oxford, 5 South Parks Road, Oxford OX1 3UB, England.

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Chapman and March have earlier proposed an interpretation of the magnetic susceptibility of expanded liquid caesium as a strongly correlated assembly of electrons in which the reduced discontinuity in the electronic momentum distribution at the Fermi surface, q say, plays a central role. Here, by considering briefly the way the electrical resistivity near criticality might depend on q, a plot is motivated which clearly testifies to an intimate relationship between a thermodynamic property, namely magnetic susceptibility, and a transport property, electronic conductivity.

KEY WORDS: Fermi surface discontinuity, many-body density matrix.

1 INTRODUCTION

Chapman and March[1] have recently given an interpretation of the observed maximum in the susceptibility of expanded fluid Cs in terms of a strongly correlated electron assembly. In their work, the reduced discontinuity, q say, at the Fermi surface in the electronic momentum distribution $n(p)$, due to switching on strong Coulombic correlations in a Fermi gas where initially $q = 1$, played a major role in the interpretation.

In parallel with this work, calculations of electrical resistivity along the liquid-vapour coexistence curve have been carried out by Chapman[2] on Cs, and later by Ascough and March[3] on Rb. In both cases, essential input into the self-consistent inclusion of a mean free path for electron–ion scattering was the measured liquid structure as made available by Hensel and coworkers[4]. Weak scattering theory remains useful for both Cs and Rb over an extended portion of the liquid–vapour coexistence curve. But, naturally enough, as both electron–ion and electron–electron interactions eventually become strong on nearing the critical point, any such approach, whether self-consistent[5] or in the original perturbative Bhatia–Krishnan–Ziman form[6,7] must fail.

Therefore, in the present work, attention is shifted to the regime of strong electron–electron correlations. It is already clear from the susceptibility treatment of Chapman and March[1] that the discontinuity q is subsuming both electron–electron and electron–ion effects, at least partially, when both are strong. Therefore the purpose of this Letter is to motivate a way in which, near the critical point, the electrical resistivity can be linked closely with the magnetic susceptibility, via the discontinuity q.

The argument rests on the so-called force-force correlation formula for electrical resistivity due to Rousseau *et al.*[8] In its original form, this is applicable only to independent electrons, though it is, at least in principle, able to handle strong electron–ion correlations. The way this approach might be generalized to incorporate strong electron–electron repulsions has already been set out by the writer[9] in considering the Hall effect in liquid metals.

Briefly, the argument rests on replacing the Dirac idempotent density matrix ρ in the RSM formula[8] for independent electrons by the fully correlated first-order density

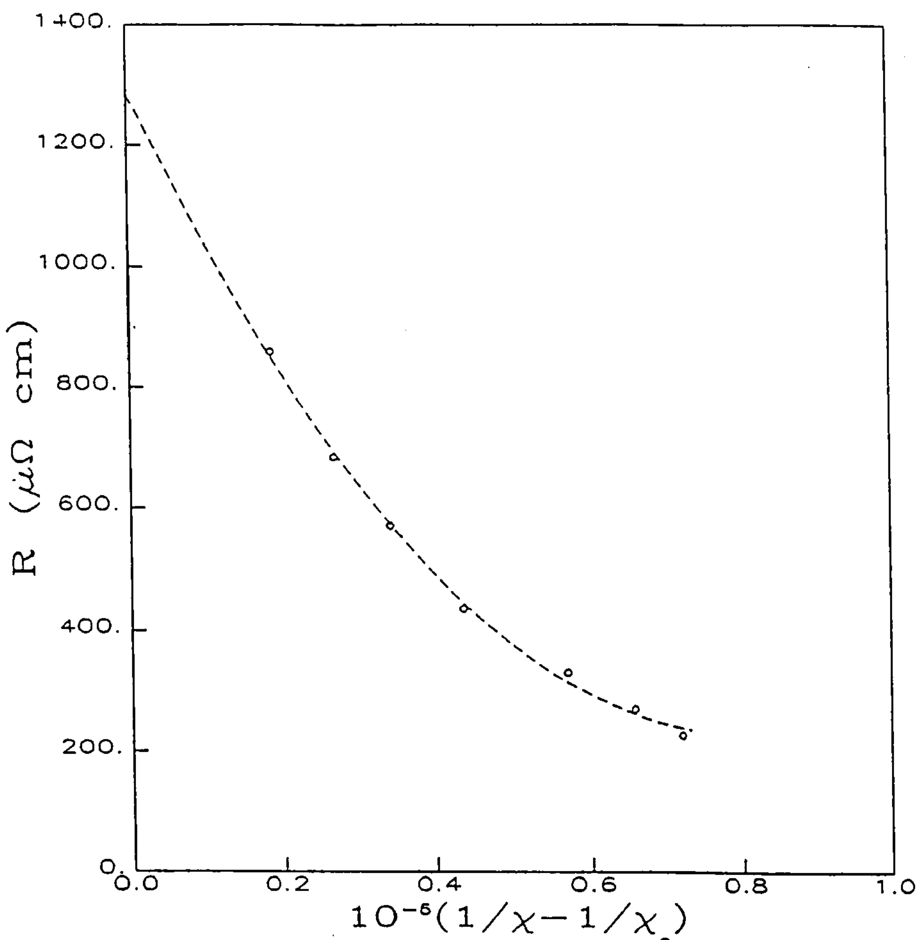

Figure 1 Shows relation between resistivity and magnetic susceptibility for expanded liquid Cs. Experimental data for R was taken from Alexseev and Iakubov[14] and from Winter *et al.*[15] while data for susceptibility is as set out in Ref. 1.

matrix γ satisfying $\gamma^2 < \gamma$. Then it is possible to remove all one-body traces from the RSM formula and to obtain the resistivity solely in terms of γ. What becomes clear is that no translationally invariant assumption about the many-body quantity γ can work in the resulting transport theory. A plausible factorization of $\gamma(\mathbf{r}_1, \mathbf{r}_2)$ is to write

$$\gamma(\mathbf{r}_1, \mathbf{r}_2) = g(\boldsymbol{\xi})h(\boldsymbol{\eta}) \tag{1}$$

where $\boldsymbol{\xi} = (1/2)(\mathbf{r}_1 + \mathbf{r}_2)$ and $\boldsymbol{\eta} = (1/2)(\mathbf{r}_1 - \mathbf{r}_2)$. Some motivation for development can be provided by the form of the one-electron density matrix discussed by March and Sampanthar[10] in an attempt to describe Wigner-like correlations[11,12] in jellium. Inserting the resulting γ into the generalized force-force correlation formula then suggests an expansion of the resistivity R in terms of the now small discontinuity q as

$$R = R_0 + qR_1 + \cdots. \tag{2}$$

So far, it has not proved possible to make first principles calculations of R_0 and R_1 from the force–force correlation function with strong electron–electron interactions. Therefore, what has been done is to return to the theory of Chapman and March[1] for magnetic susceptibility. Here it is useful to relate the magnetic susceptibility χ in the strong correlation limit to the Curie limit, χ_c say[13]. Then the quantity $(1/\chi - 1/\chi_c)$ provides an empirical measure of the discontinuity q and Eq. (2) evidently motivates a plot of the measured values of electrical resistivity R versus $(1/\chi - 1/\chi_c)$. The results are shown in the Figure*, and that there is an intimate correlation between a transport property R and a static property, namely the magnetic susceptibility, is evidently established by this plot. An admittedly long extrapolation in this Figure, shown by the dashed curve, suggests that R_0 in Eq. (2) is around 1300 $\mu\Omega$ cm.

Acknowledgments

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References

1. R. G. Chapman and N. H. March, *Phys. Rev.*, **B38**, 792 (1988).
2. R. G. Chapman, D. Phil. thesis, University of Oxford (1988).
3. J. A. Ascough and N. H. March, to be published.
4. See, for example, R. Winter and F. Hensel, *Phys. Chem. Liquids*, **20**, 1 (1989).
5. C. R. Leavens, A. H. Macdonald, R. Taylor, A. Ferraz and N. H. March, *Phys. Chem. Liquids*, **11**, 115 (1981).
6. A. B. Bhatia and K. S. Krishnan, *Proc. Roy. Soc.*, **A194**, 185 (1948); K. S. Krishnan and A. B. Bhatia, *Nature* **156**, 503 (1945).
7. J. M. Ziman, *Phil. Mag.*, **6**, 1013 (1961).
8. J. S. Rousseau, J. C. Stoddart and N. H. March, *J. Phys.*, **C5**, L175 (1972).
9. N. H. March, *Phys. Chem. Liquids*, **19**, 59 (1989).
10. N. H. March and S. Sampanthar, *Acta Phys. Hungar.*, **14**, 61 (1962).

* The writer is greatly indebted to R. G. Chapman for making the calculations on which this figure is based.

11. E. P. Wigner, *Phys. Rev.*, **46**, 1002 (1934).
12. E. P. Wigner, *Trans. Far. Soc.*, **34**, 678 (1938).
13. See W. W. Warren, *Phys. Rev.*, **B29**, 7012 (1984).
14. V. A. Alexseev and I. T. Iakubov, *Phys. Rep.*, **96**, 1 (1983).
15. R. Winter, F. Noll, T. Bodensteiner, W. Glaser and F. Hensel, *Zeits. für Phys. Chem. Neue Folge*, **156**, 145 (1988).