QUANTUM DISSIPATION FROM PHONONS; METALLIC HYDROGEN; ELECTRON-ION MIXTURES

A Dissertation

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This thesis covers a number of different topics: atomic tunneling with dissipation, the metallization of liquid hydrogen, universality of electron-ion structure factors and non-linear response theory:

Chapter 2 discusses how a phonon environment can *qualitatively* change the tunneling behaviour of an atom.

Chapter 3 gives an overview of theoretical questions related to dense fluid metallic hydrogen, as recently discovered by Bill Nellis and co-workers.

Chapter 4 shows how and why the response of a single atom in an electron gas is well approximated by linear plus second order response.

Chapter 5 demonstrates that electron-ion correlations functions $S_{eI}(k)$ fall either into the *low valence* or *high valence* classes for liquid metals.

Chapter 6 establishes some exact results for pseudo-atom densities and effective ion-ion potentials.

Biographical Sketch

I was born in Utrecht, the Netherlands, to Marijke Eva and Adriaan Mels Louis, who soon took me to Africa, the most beautiful continent on earth. There I attended Bongolo Alliance School on an isolated little mountain in the pristine Gabon rain-forest. For high school I first attended Ivory Coast Academy, Cote d'Ivoire, where I majored in soccer, initiation pranks and having fun, and finished up at the (smore academically challenging) International School of Beverweerd (in a 14th century Dutch castle!). My Drs. degree at the Rijks Universiteit Utrecht was in theoretical physics and soon afterwards I set foot on US soil (August 1992) and have lived in Ithaca ever since. After a long-awaited 3-month trip around the world, mainly visiting friends I've made at Cornell[1], I'm returning to the old world as a post-doc at Cambridge U, (UK) in January 1998.

[1] but also, perhaps to atone for the forest of trees devoured by the endless drafts of this thesis, a one-month stint working for Gabon Vert, an enviromental consulting company specializing in preservation of African rain-forests (pour un environnement en forme)

Dedicated to my parents,

Acknowledgements

"I give you thanks, Creator and God, that you have given me this joy in thy creation, and I rejoice in the works of your hands. See I have now completed the work to which I was called. In it I have used all the talents you have lent to my spirit."

–Johannes Kepler[2] –

"Science is the most jealous of mistresses!"

–Isaac Pomeranchuk[3]–

Writing acknowledgments is like trying to describe an excellent red wine. Myriads of well worn phrases exist, but just as words never fully capture the experience of a luscious Bordeaux, so our feeble acknowledgments of thanks but dimly reflect what people have meant in our lives. The last 5 years at Cornell have been among the happiest in an otherwise blissful life. The reason for this is not the Ithaca weather or even the beautiful scenery, but the multitudes of kind, friendly and stimulating people that crossed my path here. Expressing that in words is frustrating, they always fall short. On the other hand, acknowledgments are the only part of a thesis most people read, so here goes:

I've had the privilege of working with three different advisors, each of whom brought just what I needed at that stage in my career:

First and foremost, I'd like to thank my thesis advisor Neil Ashcroft. I feel very honored to have been his advisee and profit from his seemingly inexhaustible knowledge of condensed matter physics, his sharp insights, his generosity, and his careful and tactful guidance ("Let's see Ard, what's the physics here?"). I always looked forward to our Monday morning discussions which taught me about much more of the world than physics alone, and hope we can continue to collaborate together from Cambridge.

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[2] Cited in Christopher Kaiser, *Creation and the History of Science* (Eerdmans, Grand Rapids (1991)), p127.

[3] Cited in Yuri Orlov, *Dangerous Thoughts: Memoirs of a Russian Life*, (William Morrow and Company, New York (1991)), p112

Jim Sethna infected me with some of his boundless enthusiasm for physics, taught me a great deal about how to understand complicated problems in simple terms, and showed me how to have fun doing research. His guidance during my first two years here was exactly what I needed at that time, and I am very grateful for all his input and support.

Daan Frenkel was my first mentor in physics and I spent a very exciting and enjoyable few months working in his group in Amsterdam, trying to prove that entropy was really everything and getting my feet wet in that delightful process of generating new knowledge we call research. I look back with special fondness on our many late afternoon sessions in front of the white-board, where Daan taught me that asking the right questions is as important as knowing their answers.

I've also appreciated John Reppy's patience and good humor and thank him for serving on my special committee, and the Material Science Center through which the NSF funded me at Cornell (grant DMR96-24-8330).

Bill Nellis very kindly offered me the opportunity to write a paper with him on the fluid metallic phase of hydrogen that he discovered. I thoroughly enjoyed working with him, and thank him for his hospitality on my visit to Livermore. I also thank Bill Magro for teaching me much about hydrogen and path integral Monte Carlo. I thank Peter Edwards for reading through my thesis and for his useful advice. Karsten Jacobsen was also a great help on the project that fills the last three chapters of this thesis and I thank him for that.

Before I came to the US, an eminent American physics professor I hoped to work for advised me to go to the best school possible because I'd learn more from my fellow students than from anything else. Whether he said this out of altruism or to tactfully get rid of me remains to be seen, but I took his advice and came to Cornell. He was right, and I'd like to thank the many denizens of Clark and it's environs for creating such a stimulating (sorry ... using that word again), environment. Andone, Bill W, Bill E, Byard, Bruce, Dave, Iya, Jan von Delft, Geoff, Ivan, Jane', Jeff, Karen, Kurt, Lisa, Matej, Olga, Shashi and Tom immediately spring to mind. And of course thanks to my officemates, Alex, Badri, Mike and Wei-Jing, who provided many pleasant distractions, and helped make 535 the happening place to be. Special thanks go to Wei-Jing for being a good friend, consistently providing the office with food, and for being such a good sport when I threw him into the swimming pool and booby-trapped the bridal suite at his wedding.

But life here has been much more than physics alone. At the risk of missing some key people, I still would like to thank:

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