Journal of Statistical Physics, Vol. 111, Nos. 3/4, May 2003 (© 2003)

Book Review: *Quantum Mechanics and Its Emergent Macrophysics*

Quantum Mechanics and Its Emergent Macrophysics. Geoffrey L. Sewell, Princeton University Press, 2002

The goal of Geoffrey Sewell's recent book is very ambitious, since he attempts to demonstrate the link between quantum systems of many degrees of freedom and macroscopic physical laws. Much of Sewell's own research is centered around this theme with many useful insights gained. I, as a reader, opened the book with eager anticipation. Of course, one obvious problem is the sheer vastness of the subject, which comprises much of current activities in statistical and solid state physics.

Sewell's choice is to first provide a general account of the theoretical and mathematical framework, where he relies on the algebraic formulation of quantum mechanics to serve as a natural framework for dealing with infinitely extended systems. In fact, the interested reader may consult his previous Oxford University Press monograph "Quantum Theory of Collective Phenomena," which provides a gentler introduction to algebraic quantum mechanics.

With this basis, a brief summary of equilibrium statistical mechanics is given as the cornerstone and best-understood part of the theory. The topics discussed include equilibrium states, the KMS condition, linear response and thermodynamic stability, the notion of pure phases and symmetry breaking, the validity of thermodynamics, and the link between entropy and order. As an exciting application of the scheme developed, the derivation of superconductive electrodynamics is explained. In this context, to exclusively rely on the microscopic Hamiltonian would be extremely hard. To get around this difficulty Sewell simply assumes off-diagonal long range order. Still it is impressive to see how many properties can be deduced granted its validity. One major goal is to treat time-dependent phenomena. A highlight of the book is the laser model (a variant of the Hepp–Lieb study), which provides a physically relevant example in which the route

0022-4715/03/0500-1021/0

from quantum dynamics to macrophysics can be followed with mathematical rigor through each step. Otherwise certain dynamical properties, like decay of time-correlations are assumed, as, e.g., in the very concise discussion of fluctuating hydrodynamics and the associated fluctuation algebras. While such a strategy leaves open for which interaction potentials the postulated decay holds, it still sharpens our understanding on the microscopic input required for standard and well corroborated macroscopic theories.

As a reviewer, I would have liked to see important more recent developments at least mentioned. To provide one example: The decay of time-correlations is a central topic of the book. So one might ask for the class of systems for which such decay has been established on the basis of a quantum Hamiltonian. Of course, there are the free field theories with quadratic Hamiltonians. As one particular case, Sewell discusses the well beaten harmonic oscillator linearly coupled to an infinitely extended bath of harmonic oscillators. This class of models relies on the dipole approximation and on a harmonic confining potential, which are rather artificial assumptions. Through the work of Bach, Fröhlich, and Sigal (*Lett. Math. Phys.* **34**:183 (1995)), Jakšić and Pillet (*Comm. Math. Phys.* **176**:619 (1996)), and others we now know how to handle the physically more realistic case of, say, a hydrogen atom coupled to the quantized radiation field. The corresponding Hamiltonian is not quadratic and there is simply no way to rely on finding an exact solution. For this reason the works mentioned are a qualitative step ahead in our understanding of the approach to equilibrium and the decay of time-correlations.

In addition, somewhat more extended and detailed explanations on the physics of the systems under study would have been of help to the reader. Again one example has to suffice. In the introduction to Chapter 4 Sewell explains the time-reversibility of the Schrödinger equation and contrasts it with the irreversible character of macroscopic evolution equations. While he correctly emphasizes the role of macroscopic observables, the importance of the initial conditions is more hidden. As so vividly explained by J. L. Lebowitz in his article (*Physica A* **263**:516 (1999)), if both equations are supplemented with the appropriate initial conditions, the quantum dynamics will follow in approximation the macroscopic evolution over a suitably restricted time scale. But, because of time-reversibility, there are always atypical initial conditions, such that the solution to the Schrödinger equation behaves peculiarly and does not satisfy the macroscopic law.

Despite such extra wishes, Sewell deserves full credit for his attempt in providing a coherent picture of how macroscopic physical laws emerge from quantum mechanics. I am convinced that the book will serve as a strong foundation on which further research can be built. As is obvious to anyone working in this field, further efforts of research in this general area are badly needed. Only the tip of the iceberg has appeared and we are still far away from the ultimate goal of deriving macroscopic dynamics from a reasonably realistic quantum model.

Herbert Spohn
Zentrum Mathematik
Technische Universität München
Garching, Germany