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Book Review: *Chaos in Atomic Physics*

Chaos in Atomic Physics. R. Blumel and W. P. Reinhard, Cambridge University Press, 1997.

The idea of using the precision available in experimental atomic physics to check predictions of mainly numerical results of the theory of chaos is an extremely appealing one. However, the connection between atomic physics described by the linear equations of quantum mechanics and the essentially nonlinear theory of chaos seem at first glance to be at least questionable. The key to understanding the link between these two research areas lies in the fact that high energy quantum states can be described semi-classically. This crucial idea provides the connection between the subject area of chaos and molecular physics.

Hundreds of published articles and a few reviews have appeared in the last ten to twenty years which deal with the topic of chaos in atomic physics. The book under review is the first very successful attempt to summarize the main results of this research area in a monograph.

The first four chapters of the book deal with a general analysis of classical chaos while the remaining chapters are devoted to time-dependent (Chapters 5–8) and time-independent (Chapters 9–10) problems in atomic and molecular physics. The last chapter suggests some future developments in the joint area of chaos and atomic physics.

The fresh view of the authors manifests itself already in the introduction in Chapter 1 where the idea of chaos is elegantly explained in the context of a simplified version of the Sinai billiard model. Chapter 2 contains the elements of the theory of numbers, fractals, mapping and symbolic dynamics, while Chapter 3 discusses the double pendulum problem to illustrate the general approaches of Lagrangian and Hamiltonian mechanics. The first of these is perhaps more familiar to the mathematical community, and the second is more familiar to physicists. Hence both will find something familiar as well as something perhaps less well-known in these introductory chapters.

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Chapter 4 contains the authors' answer to the old question whether quantum noise exists, or whether it is only the fingerprint of chaos in an appropriate classical system. In addition to standard quantum chaos the authors consider a second type of chaos occuring in dynamically coupled quantum systems which are able to modify their (classical) time-dependent boundaries. This interesting "quantum-classical" phenomenon is connected with the uncertainty principle, which is a third type of chaos, differing from hypothetical fully quantum systems which have exponential instability and positive Lyapunov exponents. Although the existence of this class of systems is still questionable, the authors consider, as a possible candidate for experimental realization, a spin-1/2 particle moving in homogenous Stern–Gerlach apparatus which is isomorphic to the Arnold' "cat map."

As a first example, the authors consider the kicked rotor in the classical and quantum approach. The quantum picture supresses classical diffusion (Anderson localization) and quantum resonance. A real laboratory experiment—that of a CsI molecule in a microwave cavity or in a laser created grid—is suggested to allow one to find an interesting effect—a change in localization length due to a change in symmetry alone.

The mesoscopic problem posed by a microwave driven two-dimensional electron gas sprinkled onto the surface of liquid helium is considered in Chapter 6. Chaos appears for the strong fields where there are presently no analytical results available, and one must resort to numerical calculations. Methods for generating these calculations are discussed in detail. Estimates of the parameters for the consequent laboratory experiment are given.

The microwave ionization of atoms with highly excited electron states was the first experimental investigation of chaos in atomic physics. It was found that, due to the appearance of chaos, the ionization threshold will depend on field strength and not on frequency! Moreover, for high frequencies of the microwave field, an experiment has demonstrated the influence of Anderson localization. A new kind of ionization peak ("giant resonance") is predicted for bichromatically driven atoms. This has been verified in recent experiments.

A detailed analysis of the one-dimensional kicked hydrogen model is presented in Chapter 8, where the main emphasis is on the connection between the fractal structure of phase-space and the time dependence of the ionization signal. The kicked hydrogen has a power-law, rather than an exponential, signal decay. An analytical proof is given for the absence of stable islands, i.e., its phase space is fully chaotic.

Chapter 9 is devoted to a new field of chaotic scattering which is characterized by the appearance of an infinite total scattering time (classical description) or by randomness of the S-matrix and strong fluctuations of the transition probability (quantum description). Static singularities appear even in the one-dimensional set, while there is an uncountable number of dynamic singularities in higher dimensions. As a laboratory experiment to test this effect the authors suggest studying the scattering dynamics of a CsI molecule moving in the field of two (or more) mesoscopic charged wires.

The focus of Chapter 10 is on the manifestation of chaos in the helium atom (similar to that in any three-body system). Both classical and quantum calculations are performed in the study of a simplified one-dimensional model of a stretched helium atom. Along with classical chaos its quantum mechanical aspects are expressed by the complexity (infinite information content) of the density of states, and by a specific structure of energy levels and their dynamics in the complex plane. The final chapter contains recent results and trends in both theoretical and experimental quantum chaos. Some of the topics discussed are the quantum spectroscopy of classically chaotic systems, type 2 chaos, and results related to the helium atom.

The book contains a comprehensive list of references and has a style that makes it easy to read. It contains many useful physical remarks and suggestions for new experiments. It will be read with keen interest by graduate students and scientists working in this new developing branch of chaotic science, and, because of its unique features, stands out in the current literature devoted to chaos.

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