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Time in Quantum Mechanics - Vol. 2

Springer

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Preface

But all the clocks in the city
Began to whirr and chime:
'O let not Time deceive you,
You cannot conquer Time.

W. H. Auden

It is hard to think of a subject as rich, complex, and important as time. From the practical point of view it governs and organizes our lives (most of us are after all attached to a wrist watch) or it helps us to wonderfully find our way in unknown territory with the global positioning system (GPS). More generally it constitutes the heartbeat of modern technology. Time is the most precisely measured quantity, so the second defines the meter or the volt and yet, nobody knows for sure what it is, puzzling philosophers, artists, priests, and scientists for centuries as one of the enduring enigmas of all cultures. Indeed time is full of contrasts: taken for granted in daily life, it requires sophisticated experimental and theoretical treatments to be accurately "produced." We are trapped in its web, and it actually kills us all, but it also constitutes the stuff we need to progress and realize our objectives. There is nothing more boring and monotonous than the tick-tock of a clock, but how many fascinating challenges have physicists met to realize that monotony: Quite a number of Nobel Prize winners have been directly motivated by them or have contributed significantly to time measurement.[1] We feel that time flows, we feel it as an ever evolving, restless "now", and yet, from the perspective of relativity this unfolding of events at an always renewing present instant would in fact be "an illusion." Also, while the future awaits us and the past is gone, there is no time arrow making such a fundamental distinction in the microscopic equations of physics.

Physics does not capture time in its domain without residue, but it has of course much to say about time, an essential element of its theories and of our rationalization of nature. In the case of relativity, time plays a prominent, starring role:

[1] Here is a nonexhaustive list including award years: Isidor I. Rabi (1944), Charles H. Townes (1964), Alfred Kastler (1966), Norman F. Ramsey, Hans G. Dehmelt and Wolfgang Paul (1989), Steven Chu, Claude Cohen Tannoudji, and William D. Phillips (1997), John L. Hall and Theodor W. Hänsch (2005).

Einstein changed dramatically our concept of time and thus of the world. By contrast, quantum mechanics, the other great twentieth century physical theory, has paid to time a much more modest and secondary attention, and most practitioners have even refused with stubborn determination to deal with some of its evident aspects, the "time observables," in our opinion without a good or sufficient reason. Less controversial but not at all less interesting and much influential have been the fundamental contribution of quantum mechanics to improve time measurement with atomic clocks, as well as the development of techniques to study quantum dynamics and characteristic timescales, both at theoretical and experimental levels, complementary to the knowledge on the structure and properties of matter derived from time-independent methods.

The aim of a workshop series at La Laguna, Spain, since the first edition in 1994, and of this book series is to promote and contribute to a more intense interplay between time and the quantum world. This volume fills some of the gaps left by the first one, recently re-edited. It begins with a historical review in Chap. 1. Most chapters orbit around fundamental concepts and time observables (Chaps. 2–6), or quantum dynamical effects and characteristic times (Chaps. 7–12). The book ends with a review on atomic clocks in Chap. 13. Several authors have participated in "Time in Quantum Mechanics" workshops at La Laguna or Bilbao, but we have not imposed this as a necessary condition. As in the first volume, our recommendation to all authors has been to write reviews that may serve both as an introductory guide for the noninitiated and a useful tool for the expert, leaving them full freedom for the choice of emphasis and presentation.

We would like to acknowledge the work, patience, and discipline of all contributors, as well as the support of the University of the Basque Country (UPV-EHU), Ministerio de Ciencia e Innovación (Spain), EU Integrated Project QAP, EPSRC QIP-IRC, German Research Foundation (DFG), and the Max Planck Institute for Complex Systems at Dresden, where much of our work was completed within the "Advanced Study Group" "Time: quantum and statistical mechanics aspects" organized by L. S. Schulman during the summer of 2008.

Bilbao, Braunschweig, London, *J.G. Muga, A. Ruschhaupt, and A. del Campo*
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