Foreword

To commemorate the 50th anniversary of Erwin Schrödinger's death in Vienna the Erwin Schrödinger International Institute for Mathematical Physics (ESI) invited eminent scholars to meet in the city where Schrödinger was born and were he spent a good part of his life as a student and young scientist.

In 2013 the ESI will celebrate its foundation 20 years ago. It was a happy coincidence that the institute found its first quarters at Pasteurgasse 4 in the very house where Schrödinger spent his last years in Vienna. In 1997 the ESI moved to its present more spacious premises in Boltzmanngasse 5, but like in the previous housing Schrödinger's spirit continues to guide the institute's advancement.

The International Symposium "Erwin Schrödinger – 50 Years After", held January 13 to 15, 2011 in the Boltzmann Lecture Hall of the ESI, was dedicated to Erwin Schrödinger's legacy in quantum theory and to his views on the interpretation of quantum mechanics from a contemporary perspective. The symposium brought together scholars from all over the world whose scientific achievements bear evidence to Schrödinger's fundamental contributions to the development of science.

The equation that bears his name has become a trade mark and sign post far beyond the inner circles of physics, and the *Gedankenexperiment* "Schrödinger's Cat" of his famous paper of 1935, where he coined the term "entanglement" (*Verschränkung*), is still central to the discussions of the appropriate interpretation of quantum physics. It plays also an important role in recent theoretical and experimental advancements in Quantum Information Science, some of which are discussed in this volume. Indeed, since Schrödinger's paper of 1935 and the paper of Einstein, Podolsky and Rosen of that same year the question of the universality of quantum theory has not lost its pressing actuality.[1] The simple question asked by Einstein and Schrödinger (and much later by John S. Bell) about the relation between quantum mechanics and reality, i.e., the world "out there", may be disregarded as "metaphysical", but this attitude does not answer the question. A significant part of the contributions to this volume has a bearing on the still ongoing discussions of foundational issues of quantum mechanics, a topic hunting Schrödinger during all his life.

The series of lectures at the Symposium outlined recent experimental and theoretical developments related to Schrödinger's work, as well as the early developments of quantum theory and his discussions with fellow scientists. Schrödinger, like Einstein or Bohr – to name only two outstanding representatives of a wide variety of "modern" scientists – was a genuine philosopher-scientist. Therefore it is more than justified to present this side of his work from a point of view of history and philosophy of science.

[1] Erwin Schrödinger, Die gegenwärtige Situation in der Quantenmechanik. *Die Naturwissenschaften*, 23. Jahrg., Heft 48, 807–812, 823–828, 844–849, 1935. A. Einstein, B. Podolsky, N. Rosen, Can quantum-mechanical description of physical reality be considered complete? *Physical Review*, Vol. 47, 777–780, 1935.

Clearly, Schrödinger's scientific achievements are as important today as they had been when he shared the Nobel Prize in Physics for 1933. He belongs to the rare species of scholars whose ideas have became daily practice to many scientists and will continue to be part of the treasures of science. The contributions collected in this volume shed light on a few aspects of Schrödinger's multifaceted legacy. The articles collected in this volume convey the spirit which guided the presentations and vivid discussions at the Symposium.

The contribution "Erwin Schrödinger: personal reminiscences" is a verbatim transcript of the oral presentation by Walter Thirring, where he, the only one of the speakers to have known Schrödinger personally, drew a colourful picture of Schrödinger as a person, scientist and poet.

The article "Schrödinger and the genesis of wave mechanics" of Jürgen Renn contains a thorough review of the history of the Schrödinger equation together with many new insights from an ongoing research project on the history and foundations of quantum physics.

Jürg Fröhlich and Baptiste Schubnel take the question "Do we understand quantum mechanics –finally?" as a starting point for a grand tour through a conceptual and mathematical edifice where quantum mechanics finds it proper place and the differences to "realistic" theories are clearly brought out.

The contribution "Schrödinger's cat and her laboratory cousins" by Anthony J. Leggett is a verbatim transcript of his "Erwin Schrödinger Distinguished Lecture" held in Vienna on March 18, 2011. Sir Anthony's discussion of the *Gedankenexperiment* and its relation to real experiments and foundational questions is a lucid testimony of the topicality of Schrödinger's ideas.

The article "Digital and open system quantum simulation with trapped ions" by Markus Müller and Peter Zoller summarizes some recent theoretical and experimental achievements in the simulation of quantum systems that have become possible by spectacular advances in the last two decades in cooling and trapping atoms.

In the article "Optomechnical Schrödinger cats – a case for space" by Rainer Kaltenbaek and Markus Aspelmeyer, that was written specially for the proceedings, the authors describe a scenario for an experiment in space with Schrödinger cat states of unprecedented size and mass.

The article "A quantum discontinuity: the Bohr–Schrödinger dialogue" by Helge Kragh brings a lively account of the sometimes heated discussions between Niels Bohr and Schrödinger who, despite their high mutual respect for each other, had quite different views on the foundational issues of quantum mechanics.

In the contribution "The debate between Hendrik A. Lorentz and Schrödinger on wave mechanics" Anne J. Kox discusses the remarkable correspondence between the two physicists about Schrödinger's first papers on quantum theory that made the latter aware of the non-classical character of the wave mechanics he had created.

The last article of this volume, "A few reasons why Louis de Broglie discovered Broglie's waves and yet did not discover Schrödinger's equation" by Olivier Dar-

rigol is concerned with de Broglie's seminal work of 1923–24 that laid the ground for Schrödinger two years later.

The editors are deeply indebted to the contributors of this volume, for their willingness to put in writing their presentations at the Symposium, as well as enduring the subsequent tedious interventions by the editors. Our special thanks goes to Sir Anthony Leggett for making his "Distinguished Schrödinger Lecture" available for publication in this volume. Our thanks to Markus Aspelmeyer and his team for arranging the transcription of Leggett's oral presentation and designing the figures of his paper.

Besides the contributors to this volume further speakers at the Symposium were Michel Bitbol, CREA, École Polytechnique, Paris (Schrödinger's translation scheme between (abstract) representations and facts: a reflection on his late interpretation of quantum mechanics), Roberto Car, Princeton University (Quantum mechanics and hydrogen bonds), Moty Heiblum, Weizman Institute of Science (Entangled electrons in the solid state: quantum interference and controlled dephasing), K. Birgitta Whaley, University of California, Berkeley (Quantum coherence and entanglement in biology) and Anton Zeilinger, University of Vienna Wien and IQOQI Vienna (The career of Schrödinger's entanglement from philosophical curiosity to quantum information).

As a final remark we note that neither Schrödinger's late and frustrated contributions to unified field theory, nor his writings on philosophy related to quantum physics influenced by the Vedic tradition, are covered in this volume. These topics still await an extensive discussion in the literature reflecting the philosophical thinking of this eminent scholar of 20th century science and philosophy. In fact, Schrödinger developed quite early a strong inclination for philosophy, and, as mentioned in Walter Thirring's contribution, he planned in 1918 to accept a post as professor for theoretical physics at the then Austrian University in Czernowitz (today Chernivtsi, Ukraine) intending to dedicate a good part of his work to philosophy. The fall of the Habsburg Empire ended this early dream. The complex life and intellectual carrier of Erwin Schrödinger certainly merits further study.

We are indebted to Peter Graf of the University of Vienna's Central Library for Physics for providing photos.

Mrs. Ruth Braunizer, Schrödinger's daughter, attended the Symposium as a guest of honour. We are grateful to Mag^a. Verena Tomasik, Schrödinger's granddaughter, for her careful transcription of Walter Thirring's oral presentation.

The Symposium was generously supported by Professor Georg Winckler, the Rektor of the University of Vienna. The co-operation with the City of Vienna's lecture series "Vienna Lecture" and the efforts of Professor Hubert Christian Ehalt in organising a public lecture for Jürgen Renn is gratefully acknowledged.

We owe special thanks to Mrs. Irene Zimmermann for many valuable suggestions and her proofreading of all the papers during the final stage of the preparation of the volume. Finally, we wish to thank Manfred Karbe of the European Mathematical Society Publishing House for his support and constant help in producing this volume.

The editors hope that this small volume by merging technical papers with those of historical research contributes to the memory of a great physicist, a scholar of incom-

passing cultural passions and a man – repeatedly dislocated by the political turmoil of the short 20th century (E. Hobsbawn) – of outstanding human, scientific and philosophical sophisitication.

Vienna, March 2013

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