

## Preface

*This Festschrift is dedicated to Helge Holden  
on the occasion of his 60th birthday.*

Helge Holden was born to parents Finn Holden (1928–), a textbook author, historian, and high school teacher, and Kirsten nee Wolfhagen (1931–1999), a librarian and psychologist, on September 28, 1956, in Oslo, Norway. Helge grew up with two younger brothers, Steinar, who is professor of economics at the University of Oslo, and Lars, who is Managing Director at the Norwegian Computing Center in Oslo. Interestingly, Helge has a joint paper [58]<sup>1</sup> with his two brothers.

Helge decided early to study mathematics and physics, and after serving the mandatory one year military service, he entered the University of Oslo in 1976. In the fall of 1980 he started to work on his *cand. real.* thesis with the late Prof. Raphael Høegh-Krohn (1938–1988) as advisor, working on solvable models in non-relativistic quantum mechanics. In the fall of 1981 he graduated with the *cand. real.* exam, his grades being so impressive that the result was reported to the King of Norway in the Council of State.

Raphael Høegh-Krohn – a charismatic and brilliant mathematical physicist at the University of Oslo – brought Helge in contact with the group around Prof. Sergio Albeverio in Bochum, and the young mathematicians Fabio Martinelli, Werner Kirsch, and, Fritz Gesztesy. Fritz came to Oslo because he had found an improvement in an important paper by Raphael and Sergio (marking the beginning of an intensive collaboration with both of them), and at that occasion Fritz and Helge also started working together, and have continued to do so ever since. In those days, the work centered around so-called point interaction models in nonrelativistic quantum mechanics, and resulted in the book <sup>β</sup>[1], published by Springer in 1988, translated into Russian, and re-issued in a 2nd edition by the American Mathematical Society with an appendix by Prof. Pavel Exner in 2005. It has established itself as the standard reference in the field, and it is frequently cited in both the physics and mathematics literature.

In the early 1980s, Norway was going through rapid and dramatic development. At Christmas of 1969, the first oil was discovered in the North Sea – the Ekofisk field – still one of the largest in the North Sea. The question was how to take advantage

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<sup>1</sup>Numbers refer to the complete list of publications.

of this to the benefit of Norwegian society. Fortunately, the government decided to build up national competency in Norway, resulting in a dramatic improvement in the standard of living in Norway. Those who visited Norway in the early '80s and visit now, will see an extreme makeover in Norway – it simply is a different country now. In the early '80s, the Norwegian oil companies Saga, Hydro, and Statoil needed scientists with a good background in the sciences and in mathematics, and the companies supported mathematical research. Raphael and Helge, together with Nils Henrik Risebro, Lars Holden, Tore Gimse, Kyrre and Frode Bratvedt, and Christian Buchholz, embarked on the project to develop a full scale petroleum reservoir simulator. The approach was based at first on lots of enthusiasm and, retrospectively, less on deep knowledge of reservoir simulation; it was also the start of a life-long collaboration between Helge and Nils Henrik. Unfortunately, Raphael suddenly passed away in 1988, and Helge took over as PhD advisor of Nils Henrik and Lars. The development of the reservoir simulator subsequently changed focus, but it is to this day still used by Schlumberger – the world's leading oil field services company.

At this time there was essentially no activity in partial differential equations in Norway. Together with Prof. Ragnar Winther in Oslo, Helge and Ragnar have, together with their substantial number of students, been instrumental in developing the field of partial differential equations into one of the strongest areas of Norwegian mathematics. The research is no longer restricted to topics relevant to flow in porous media, and a special focus has been to understand the interaction between theoretical results and numerical simulations. There are now strong research groups in partial differential equations at the universities in Oslo, Bergen, and Trondheim, in addition to that at SINTEF.

After completion of his PhD, Helge went for the academic year 1985–86 to the Courant Institute of Mathematical Sciences of New York University on a Fulbright scholarship to join the group of Prof. James Glimm. While there, he was offered a permanent position at the Norwegian Institute of Technology (now NTNU – the Norwegian University of Science and Technology), in Trondheim, Norway, and he has remained at NTNU ever since. He spent the spring semester 1989 at the California Institute of Technology, with Prof. Barry Simon, and the academic year 1996/97 at the University of Missouri, Columbia, with Fritz.

Helge's mathematical activity spans several areas. Starting out in mathematical physics, focusing on nonrelativistic quantum mechanics, he later turned his interest to nonlinear partial differential equations. Here the interest initially was concentrated on the study of flow of hydrocarbons in porous media, and the most important mathematical results came in the theory of hyperbolic conservation laws, where, together with Nils Henrik, he wrote the book <sup>β</sup>[4] that represents the standard presentation of the so-called front-tracking approach to hyperbolic

conservation laws. With the group of Prof. Bernt Øksendal in Oslo, Helge worked on stochastic differential equations using the so-called white noise approach, and their results were presented in the book <sup>β</sup>[2]. With Fritz, Helge's interest turned to completely integrable systems – where the celebrated KdV equation is one of the most recognized examples – and they collected their results in the two-volume treatise <sup>β</sup>[5, 6], the second volume written jointly with Johanna Michor and Gerald Teschl. Subsequently, Helge's interest moved to the Camassa–Holm equation, which he had already studied with Fritz in the algebro-geometric setting. Now the problem turned into the study of an evolution equation whose solutions encounter wave breaking, and this study led to further work also on the nonlinear variational wave equation. In this area he worked with Xavier Raynaud and Katrin Grunert. His most recent book discusses so-called operator splitting methods for nonlinear partial differential equations with rough solutions, and is joint with Knut-Andreas Lie, Kenneth H. Karlsen, and Nils Henrik <sup>β</sup>[7].

A common feature of all of his work is the deep interaction between mathematics and physics. To date, he has co-authored well over 160 publications and 7 books (4 of which are already in 2nd edition, a rare feat). Helge truly enjoys collaboration and to this day has worked with well over 60 collaborators. His work has been extensively cited, according to MathSciNet, almost 2491 times by more than 1631 researchers.<sup>2</sup>

Helge has received numerous honors, among which we mention the following:

- Election to the Norwegian Academy of Science and Letters
- Election to the Royal Norwegian Society of Sciences and Letters
- Election to the Norwegian Academy of Technological Sciences
- Election to the European Academy of Sciences
- Fellow, American Mathematical Society
- Fellow, Society for Industrial and Applied Mathematics (SIAM)
- He gave an invited talk at the European Congress of Mathematics in Stockholm in 2004.

At NTNU Helge has been involved in several activities – he has had a staggering number of almost 90 master students and 24 PhD students (3 currently), most of whom are active researchers with successful careers of their own, and he is currently serving on the Board of NTNU. In 1993 he took the initiative to organize an annual *Lars Onsager Lecture* and *Lars Onsager Professorship* at NTNU to commemorate the iconic Lars Onsager (1903–76), Nobel Laureate in Chemistry in 1967, whose Alma Mater was the Norwegian Institute of Technology; 25 years later this activity is still going strong.

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<sup>2</sup>MathSciNet, April 1, 2017. *No, not an April fools joke!*

Historically, NTNU has had a strong focus on engineering with a constant source of excellent students coming from the program in *Industrial Mathematics*, developed together with partners in ECMI – *European Consortium of Mathematics in Industry*. Helge got involved with this activity through the late Prof. Henrik Martens (1927–93) at NTNU, who was one of the founders of ECMI. Helge served as President of ECMI during the period 2004–06.

On the national scene, Helge has been exceptionally active. He chaired several key panels of the Research Council of Norway for extended periods, the most important being the panel that decided on all national individual research grants in mathematics and the natural sciences. In the Scandinavian countries, Helge has chaired evaluations of research and education in mathematics at several universities in Denmark and Sweden. Similarly, on the European scene, Helge has chaired the panel of the *European Research Council* that awards the prestigious Consolidator Grants in Mathematics.

Helge has written numerous articles in Norwegian newspapers and journals on various research political topics and the popularization of mathematics. He has been very actively involved in the Abel Prize in Mathematics since its start in 2003. In particular, he served as Chair of the Abel Board of the Norwegian Academy of Science and Letters, for the period of 2010–14. During his chairmanship several novel activities started, for instance, the competition *UngeAbel*, the *Heidelberg Laureate Forum*, and the collaboration with *Petroleum Geo-Services*. He also took the initiative to edit books about the Abel Laureates, and with Ragni Piene two volumes have been completed <sup>ε</sup>[7, 12], with a third volume currently in preparation.

Helge has always been a strong proponent of international collaboration, and he served as Secretary (2003–06) and Vice President (2007–10) of the *European Mathematical Society*. Currently he is serving as Secretary of the *International Mathematical Union* (IMU), with headquarters in Berlin, Germany.

He has served on the Board of the Norwegian Academy of Technological Sciences and the Royal Norwegian Society of Sciences and Letters, and during the period 2014–16 he served as President of the latter.

While this hints at some account of Helge as the scientist and his substantial service to our profession in the national as well as international arena, we would be amiss not to comment on some personal aspects of our longstanding friendship with him. His kind, yet firm, demeanor, his integrity and sense of fairness, his dedication to science, his intellectual curiosity about the world as a whole, substantially transcending the natural sciences, his deep interest in the arts, and especially, his love of literature, shows him to be the complex and multi-faceted personality we all came to appreciate so much over the years. Several of the editors are collaborators of Helge's, some for up to 35 years now, all of us view him as a dear and trusted friend.

The volume at hand is based to some extent on the conference, *Non-linear PDEs, Mathematical Physics and Stochastic Analysis*, held at NTNU, Trondheim, July 4–7, 2016 (<https://wiki.math.ntnu.no/holden60>). The fields represented in the contributions to this volume reflect to a large degree Helge’s longstanding research interests. They center around infinite-dimensional analysis (integrals of probabilistic and oscillatory type), linear and nonlinear partial differential equations (including discrete evolution equations, Ostrovsky–Hunter-type equations, modeling crowd dynamics, porous medium type equations, nonlinear degenerate anisotropic hyperbolic-parabolic equations, Riemann problems for models of polymer flooding, systems of conservation laws, nonlinear dispersive PDEs, compensated compactness and isometric immersions of manifolds), stochastic analysis (optimal control for a system of stochastic Volterra equations), spectral theory (including spectra of leaky surfaces, Hardy–Rellich-type inequalities, dispersion estimate for one-dimensional Schrödinger operators, Schrödinger operators involving the Heisenberg sub-Laplacian), completely integrable systems (including the modified two-component Camassa–Holm system), random matrix theory, and chaotic dynamics and sestina poetry.

Finally, we express our sincere gratitude to the staff at the EMS, particularly, Thomas Hintermann, for their help, support, and expertise in producing this volume. We also thank all authors for their contributions and the referees for their invaluable assistance.

*Happy Birthday*, Helge, we hope this volume brings some fond memories and joy!

*Fritz Gesztesy*  
*Harald Hanche-Olsen*  
*Espen R. Jacobsen*  
*Yurii Lyubarskii*  
*Nils Henrik Risebro*  
*Kristian Seip*