PHYSICS FOR SECURE AND EFFICIENT SOCIETIES

Christian Beck[1] and Felicia Barbato[2] – DOI: https://doi.org/10.1051/epn/2022506
[1] Queen Mary University and Alan Turing Institute, London, UK – [2] Gran Sasso Science Institute, Italy

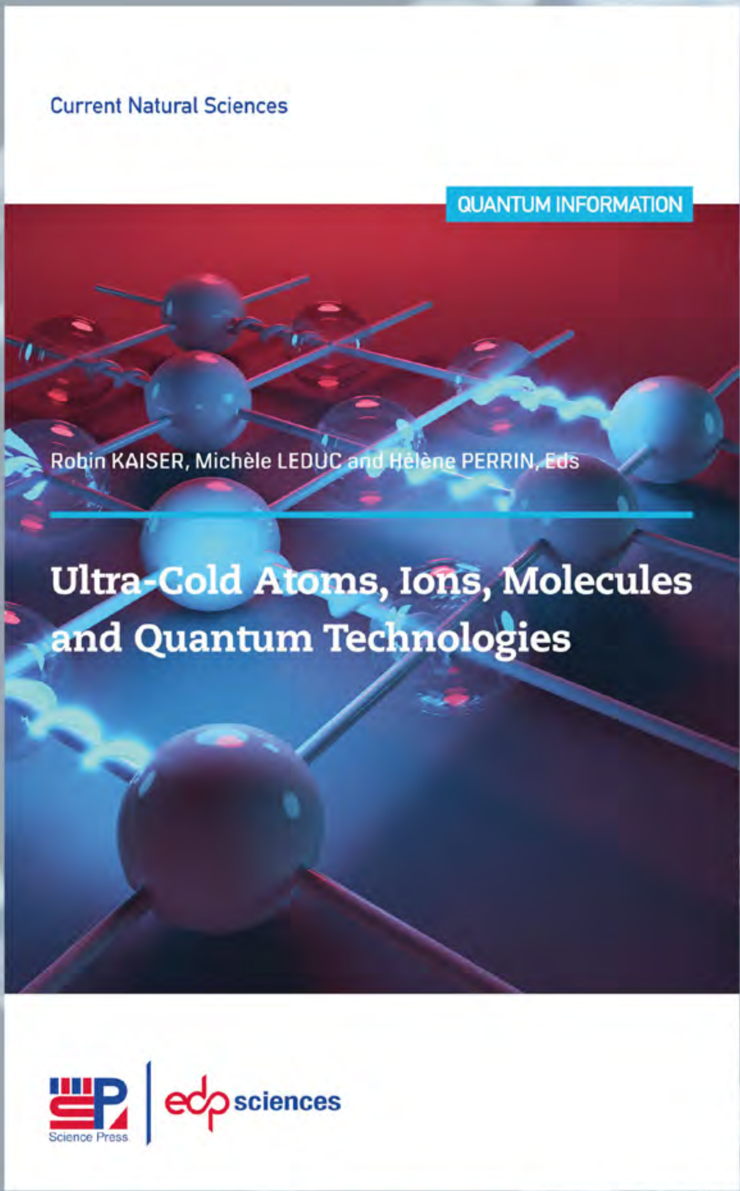
Physics research contains two very different aspects–there is the fundamental research driven by curiosity, with the ultimate aim of understanding very small interacting systems, very large interacting systems, and the complex behaviour on intermediate scales, but there is also the applied side, where physics is applied to develop new technologies, new analysis methods and new concepts and insights that are useful for society. Read about it in Chapter 6 of the EPS Grand Challenges for Physics.

▲FIG. 1: Augmented reality and smart sensors will allow greater control of production processes

Ultimately, much of what physics for interacting systems encounters with is nonlinear, high-dimensional, and complex, and the final goal is to apply novel physical insights to real-world systems, providing useful applications that are helpful for society in general. The topic of this chapter, physics for secure and efficient societies, is very broad and general, and has many different aspects, and our chapter in no way makes an attempt to treat it in full generality. Rather, we have selected a few topics that we find particularly interesting, with the emphasis of looking into the future—perhaps looking towards the year 2050 or towards a similar time scale.

Now available in English !

'Ultra-cold atoms, ions, molecules and quantum technologies'



BY
Robin Kaiser,
Michèle Leduc,
Hélène Perrin

Also available in e-book format
For sale on laboutique.edpsciences.fr

ISBN : 978-2-7598-2745-9
192 illustrated pages
Price : 95 €
Available December 1, 2022

This book is the English translation of 'ATOMES, IONS, MOLÉCULES ULTRAFROIDS ET TECHNOLOGIES QUANTIQUES' that was awarded a **Special Prize** by the jury of the **'Prix Roberval 2022**' in the category 'Academic books'.

The field of cold atoms was born fourty years ago and today remains a theme regularly awarded Nobel Prizes and at the forefront of physics research. The book presents the most recent developments and traces the exceptional growth of this field over the last ten years.

Robin KAISER is Research Director at CNRS, Institut de physique de Nice, Université de la Côte d'Azur.
Michèle LEDUC is Research Director emeritus at CNRS, Laboratoire Kastler-Brossel, École Normale Supérieure, Paris.
Hélène PERRIN is Research Director at CNRS, Laboratoire de physique des lasers, Université Sorbonne Paris Nord.

Prix Roberval

Read more in Chapter 6 of the EPS Grand Challenges for Physics.

Quantum computing. One important aspect for the future of society is the further development of information technologies—proper communication and information processing and enhanced computer development is absolutely essential. Our world today is dominated by computers in their various shapes and sizes, from small to big, from personal to institutional, from local to world-wide. Science has made immense progress by implementing modern machine learning technologies and artificial intelligence, so a natural question is where is computing going to, what is the next generation of computers made of, and what is the next generation of algorithms? Still in its infancy today, quantum computing may hold the key for outstanding novel computational developments of the future—some problems are so complex that they can't be solved with present conventional computers, but require something that is orders of magnitudes faster, or need algorithms and novel approaches that are very different from what is currently used in mainstream simulations.

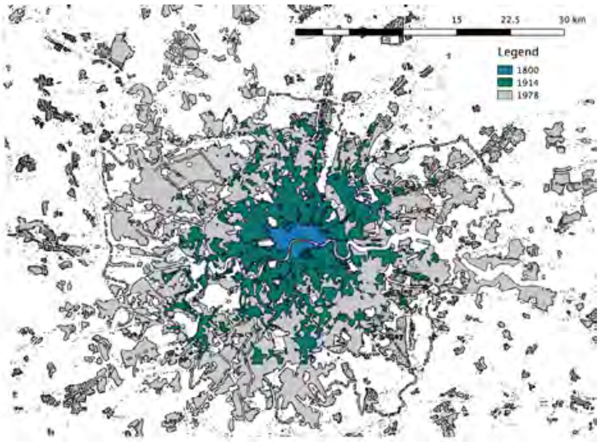
The article by Daniel Malz and J. Ignacio Cirac in our chapter summarises the most important principles of quantum computing, exploiting quantum superpositions and entanglement for the purpose of future quantum computers. The aim is to solve certain problems much faster than with conventional computers. In addition to this, the article by Zeki Can Seskir and Jacob Biamonte looks at the historical development of quantum computing research and in particular quantum algorithms and new types of machine learning models, which are expected to be very relevant in the future.

▾ **FIG. 2:** The Galileo System constellation.

Sensor development. How do we actually get the data that we feed into our physical models, to make accurate predictions for the future, using the best computers and analytical techniques available? The problem is non-trivial, as bad data yield biased and unprecise predictions. Sensor technology has made immense progress recently. The convergence of multiple technologies, real-time analytics, machine learning, ubiquitous computing, embedded systems gave birth to the Internet of Things (IoT) and the automation and control of industrial processes can be seen as the fourth industrial revolution, also known as the Industrial Internet of Things (IIoT) [Figure 1]. In her article, Antigone Marino walks in the historical basic steps of sensor developments arriving then at the future challenges set by Europe climate change strategy for 2050. In this framework, smart sensors are fundamental for monitoring all services related to the automation of processes as regards to the sphere of waste reduction, clean water, environmental control and finally to expand the quality of life in the workplace.

Space exploration. The use of smart sensors is also open to the space sector which is gaining more and more importance and is going to enter in its golden age driven by the longstanding dream of mankind, the space exploration, with many interesting new perspectives and applications for the benefit of humans on the horizon. In his article on the space sector, Javier Ventura-Traveset reviews the current status of next future missions and explores the prospects of the space sector beyond 2030/2035. Many intriguing topics are covered, starting from more gnoseological problems like space science, going through futuristic scenarios about human and robotic exploration of space, and finally touching more practical issues like understanding the climate change trend, its sources, its dynamics and the major anthropogenic impacts. In this article, Javier Ventura-Traveset makes it very clear how space exploration has, and will have even more in the future, huge impact on our society both from the economical and the social point of view, and how future society can benefit from this emerging sector [Fig. 2].

Complex systems. Finally, another problem of utmost relevance for future societies is the understanding of the complexity that is underlying the real-world systems that surround us and the daily life aspects of our living. Here statistical physics, in its modern form, has a lot to say.



▲ **FIG. 3:** A city.

One particular example is the science of cities [Fig. 3]. A very large part of the world population these days live in cities, but how do cities actually function, how do they evolve, how can we improve the day-to-day structures and life quality in a sustainable and environmentally friendly way? Cities are spatially extended complex systems, and statistical physics, in its modern formulation, can be applied. In the historical Boltzmann formulation particles are replaced by agents (companies, vehicles, people, sustainable energy sources, ...), interactions are replaced by communications (mobile phones, e-mail, Twitter, ...) , phase transitions correspond to an abrupt change of relevant observables (opinions, prices, behavioural patterns, ...) , and so on. In his article Marc Barthelemy provides a state-of-the-art overview on city modelling, city growth aspects, traffic congestion, and much more, using the tools of statistical physics and complex network theory.

Overall, the example topics treated in this chapter show that often there is initially fundamental basic physical science, which then feeds into more advanced applied models relevant for the future development. For example, starting from quantum physics we proceed to modern methods and algorithms of quantum computing, starting from classical equilibrium and nonequilbrium statistical physics we proceed to a modern science of cities, and so on. Better predictions and better models can be made if we have access to better data, obtained with more powerful sensors, by better satellite navigation methods, and so on. Let's hope that in 2050, most of the world's population will be living in a clean, peaceful and sustainable environment, where physics helped a lot to attain this stable state. ■

Acknowledgements

The authors would like to thank Marc Barthelemy, Jacob Biamonte, Ignacio Cirac, Daniel Malz, Antigone Marino and Javier Ventura-Traveset for their precious contributions to the Grand Challenges.