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The Cosmic Web

By John Richard Gott

Princeton University Press

The observation of the night sky is as old as humankind itself. Cosmology, however, has only achieved the status of “science” in the past century or so. In this book, Gott accompanies the reader through the birth of this new science and our growing understanding of the universe as a whole, starting from the observation by Hubble and others in the 1920s that distant galaxies are receding away from us. This was one of the most important discoveries in the history of science because it shifted the position of humans farther away from the centre of the cosmos and showed that the universe is not eternal, but had a beginning. The philosophical implications were hard to digest, even for Einstein, who invented the cosmological constant such that his equations of general relativity could have a static solution.

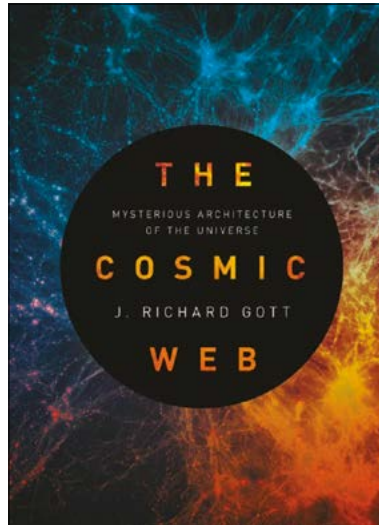
Following the first observations of distant galaxies, astronomers began to draw a comprehensive map of the observable universe. They played the same role as the explorers travelling around our planet, except that they could only sit where they were and receive light from distant objects, like the faded photography of a lost past.

After an introduction to the early days of cosmology, the book becomes more personal, and the reader feels drawn in to the excitement of actually doing research. Gott’s account of cosmology is given through the lens of his own research, making the book slightly biased towards the physics of the large-scale structure of the universe, but also more focused and definitely captivating for the reader.

The overarching theme of the book is the quest to understand the shape of the “cosmic web”, which is the distribution of galaxies and voids in a universe that is homogeneous only on very large scales. Tiny fluctuations in the matter density, ultimately quantum in origin, grow via gravity to weave the web.

In graduate school, under the supervision of Jim Gunn, Gott wrote his most cited paper, proposing a mathematical model of the gravitational collapse of small density fluctuations. Here, the readers are given a flavour of the way real research is carried out. The author describes in detail the physics involved in the topic, as well as how the article was born and completed and how it took on a life of its own to become a classic.

The author’s investigation of the large-scale structure intertwines with his



passion for topology. He was fascinated by polyhedrons with an infinite number of faces, which were the subject of an award-winning project that he developed in high school and of his first scientific article published in a mathematics journal.

At the time, when astronomical surveys were covering only a small portion of the sky, it was unclear how the cosmic structures assembled. American cosmologists thought that galaxies gathered in isolated clusters floating in a low-density universe, like meatballs in a soup. On the other hand, Soviet scientists maintained that the universe was made up of a connected structure of walls and filaments, where voids appear like holes in a Swiss cheese.

Does the 3D map of the universe resemble a meatball stew or a Swiss cheese? Neither, Gott says. With his collaborators, he proposed that the cosmic web is topologically like a sponge, where voids and galaxy clusters form two interlocking regions, much like the infinite polyhedrons Gott studied in his youth.

The reader is given clear and mathematically precise descriptions of the methods used to demonstrate the idea, which was later confirmed by deeper and larger astronomical observations (in 3D), and by the analysis of the cosmic microwave background (in 2D). By that time, we had the theory of cosmological inflation to explain a few of the puzzles regarding the origin of the universe. Remarkably, inflation predicts tiny quantum fluctuations in the fabric of space–time, giving rise to a symmetry between

higher and lower density perturbations, leading to the observed sponge-like topology.

Therefore, by the end of the 20th century, the pieces of our understanding of the universe were falling into place and, in 1998, the discovery that the universe is accelerating allowed us to start thinking about the ultimate fate of the cosmos. This is the subject of the last chapter, an interesting mix of sound predictions (for the next trillion years) and speculative ideas (in a future so far away that it is hard to think about), ending the book with a question – rather than an exclamation – mark.

This is not only a good popular science book that achieves a balance between mathematical precision and a layperson’s intuition. It is also a text about the day-to-day life of a researcher, describing details of how science is actually done, the excitement of discovery and the disappointment of following a wrong path. It is a book for readers curious about cosmology, for researchers in other fields, and for young scientists, who will be inspired by an elder one to pursue the fascinating exploration of nature.

● Guido D’Amico, CERN

Calorimetry: Energy Measurement in Particle Physics (2nd edition)

By Richard Wigmans

Oxford Science Publications

Also available at the CERN bookshop

When the first edition of this book appeared in 2000, it established itself as “the bible of calorimetry” – not only because of the exhaustive approach to this subtle area of detection, but also because its author enjoyed worldwide recognition within the field. Wigmans gained it thanks to his ground-breaking work on the quantitative understanding of so-called compensating calorimeters (i.e. how to equalise the response of such detectors for electromagnetic and hadronic interactions) and to the leading role he played in designing and operating large detectors that are still considered to be state of the art.

As with the real Bible, which underwent several revisions, this book has been reviewed in depth and published in a second edition. The author has updated it to take into account the last 16 years of progress in the field and to improve its impact as a reference for both students and practitioners.

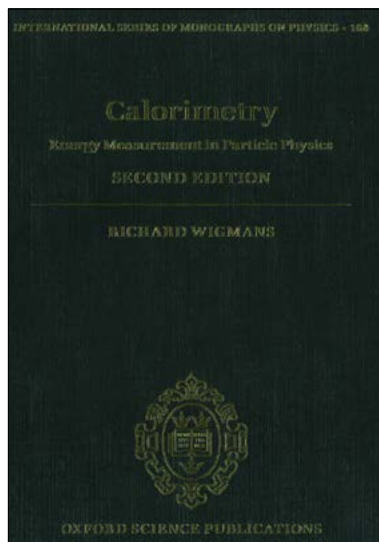
At first look, one immediately notices that considerable work has been put into improving the quality of the graphics and figures – introducing colours where

appropriate – and this new edition is available as an e-book. But there is much more to this updated version.

Chapters two to six, in which the fundamentals of calorimetry are discussed, follow the same thorough structure of the first edition, but they include new insights and use more recent data for illustration, mostly coming from the LHC experiments. Chapters one (Seventy Years of Calorimetry), seven (Performance of Calorimeter Systems) and 11 (Contributions of Calorimetry to the Advancement of Science) have also been brought up to date. Chapters eight, nine and (to a large extent) 10 are brand new and, in my opinion, represent the real added value of this new edition. In particular, chapter eight (New Calorimeter Techniques) discusses the two most relevant innovations introduced in the field during the past decade: dual-readout calorimetry (DRC) and particle-flow analysis (PFA).

The concept of DRC is elaborated upon to circumvent the limitations of compensating hadron calorimeters. Their performances depend crucially on the detection of the abundant contribution of the neutrons produced in the hadronic shower development, which in turn requires the use of heavy absorbers and a small sampling fraction – with the consequent loss of resolution for electromagnetic showers – as well as a relatively large signal-integration time and volume. In DRCs, signals coming from scintillation and Cherenkov processes provide complementary information about the shower development and allow the measurement of the electromagnetic fraction of hadron showers event by event, thus eliminating the effects of fluctuations on calorimeter performance. This concept is discussed in depth and predictions are compared with R&D results on prototypes, providing a convincing experimental demonstration of this novel technique. Although no full-scale calorimeter of this type has been built so far, the results obtained with real detectors, combined with Monte Carlo simulations, have outlined the breakthrough power of this idea, which has all the potential to rival the performances of the best compensating calorimeters, with much better energy resolution for electromagnetic showers. It is very stimulating food for thought for whoever is poised to design next-generation calorimeters.

The other important topic discussed in chapter eight, PFA, is a completely different method that is being used to improve calorimeter performances for jets. It is based on the combined use of a precision tracker and a high-granularity calorimeter, which



measures the momentum of charged-jet particles and the energy of neutral particles, respectively. High granularity is mandatory to avoid double counting of the charged particles already measured by the tracker. The topic is treated in great detail, with abundant examples of the application of this technique in real experiments, and its pros and cons are discussed in view of future large-scale detector systems.

As an example, the idea that one can relax the requirements on the calorimeters, since they measure on average only one third of the particles in a jet while the remaining two thirds are very well measured by the tracker, is strongly questioned because the jet-energy resolution would be dominated by the fluctuations in the fraction of the total jet energy that is carried by the charged fragments.

Chapter nine (Analysis and Interpretation of Test Beam Data) is a brand-new addition that I find extremely illuminating and will be valuable for more than just newcomers to the field. By going through it, I have retraced the path of some of my mistakes when dealing with calorimeters, which are complex and subtly deceptive detectors, often exhibiting counterintuitive properties.

Finally, chapter 10 (Calorimeters for Measuring Natural Phenomena) is a tribute to the realisation and successful employment of calorimetric systems to the study of natural phenomena (neutrinos, cosmic rays) in the Antarctica, the Mediterranean Sea and the Argentinian pampa, inside a variety of mountains and deep mines, and in space.

In summary, this second edition of *Calorimetry* fully meets the ambitious goals

of its author: it is a well written and pleasant book, a reference manual for both beginners and experts, and a source of inspiration for future developments in the field.

● Sergio Bertolucci, University of Bologna

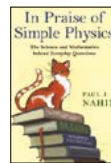
Books received

In Praise of Simple Physics: The Science and Mathematics behind Everyday Questions

By Paul J Nahin

Princeton

Also available at the CERN bookshop



In this book, popular-science writer Paul Nahin presents a collection of everyday situations in which the application of simple physical principles and a bit of mathematics can make us understand how things work. His aim is to take these scientific disciplines closer to the layperson and, at the same time, show them the wonder lying behind many aspects of reality that are often taken for granted.

The problems presented and explained are very diverse, ranging from how to extract more energy from renewable sources, how best to catch a baseball, to how to measure gravity in one's garage and why the sky is dark at night. These topics are treated in an informal and entertaining way, but without waiving the maths. In fact, as the author himself highlights, he is interested in keeping the discussions simple, but not so simple that they are simply wrong. The whole point of the book is actually to show how physics and some calculus can explain many of the things that we commonly encounter.

Engaging and humorous, this text will appeal to non-experts with some background in maths and physics. It is suited to students at any level beyond the last years of high school, as well as to practicing scientists who might discover alternative, clever ways to solve (and explain) everyday physics problems.

The Black Book of Quantum Chromodynamics: A Primer for the LHC Era

By J Campbell, J Huston and F Krauss

Oxford University Press

Also available at the CERN bookshop



This book provides a comprehensive overview of the physics of the strong interaction, which is necessary to analyse and understand the results of current experiments at particle accelerators. In particular, the authors aim to show how to apply the

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framework of perturbative theory in the context of the strong interaction, to the prediction as well as correct interpretation of signals and backgrounds at the Large Hadron Collider (LHC).

The book consists of three parts. In the first, after a brief introduction to the LHC and the present hot topics in particle physics, a general picture of high-energy interactions involving hadrons in the initial state is developed. The relevant terminology and techniques are reviewed and worked out using standard examples.

The second part is dedicated to a more detailed discussion of various aspects of the perturbative treatment of the strong interaction in hadronic reactions. Finally, in the last section, experimental findings are confronted with theoretical predictions.

Primarily addressed at graduate students and young researchers, this book can also be a helpful reference for advanced scientists. In fact, it can provide the right level of knowledge for theorists to understand data more in depth and for experimentalists to be able to recognise the advantages and disadvantages

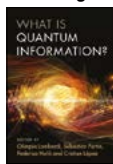
of different theoretical descriptions.

The reader is assumed to be familiar with concepts of particle physics such as the calculation of Feynman diagrams at tree level and the evaluation of cross sections through phase space integration with analytical terms. However, a short review of these topics is given in the appendices.

What is Quantum Information?

By O Lombardi, S Fortin, F Holik and C López (eds.)

Cambridge University Press



This book debates the topic of quantum information from both a physical and philosophical perspective, addressing the main questions about its nature. At present, different interpretations of the notion of information coexist and quantum mechanics brings in many puzzles; as a consequence, says the author, there is not yet a generally agreed upon answer to the question “what is quantum information?”.

The chapters are organised in three parts. The first is dedicated to presenting various

interpretations of the concept of information and addressing the question of the existence of two qualitatively different kinds of information (classical and quantum). The links between this concept and other notions, such as knowledge, representation, interpretation and manipulation, are discussed as well.

The second part is devoted to the relationship between informational and quantum issues, and deals with the entanglement of quantum states and the notion of pragmatic information. Finally, the third part analyses how probability and correlation underlie the concept of information in different problem domains, as well as the issue of the ontological status of quantum information.

Providing an interdisciplinary examination of quantum information science, this book is aimed at philosophers of science, quantum physicists and information-technology experts who are interested in delving into the multiple conceptual and philosophical problems inherent to this recently born field of research.

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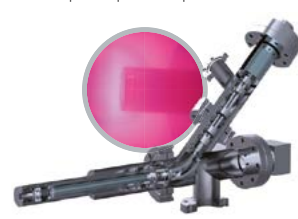
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