importance that theories can have for the history of science, even when they are ultimately shown to be wrong. Wrong ideas do not always hinder the progress of science — they can even have positive consequences. Spurred on by the impossibility of solving the controversy with a single crucial experiment, scientists were engaged in a gigantic and often acrimonious hunt for biological findings in the hope of shifting the balance in one direction or another.

In the course of this battle, as Harris shows, many standard microbiological instruments were conceived, which influenced, and still influence, everyday laboratory life and the food industry (such as swan-necked flasks, cotton-wool air filters and autoclaves). So the wrong theory of generation without seeds was itself the seed of many ideas that had an enormous positive influence on the development of the microbiology and pathology of infectious diseases. ■

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Gases get cool

Lévy Statistics and Laser Cooling: How Rare Events Bring Atoms To Rest
by François Bardou, Jean-Philippe Bouchaud, Alain Aspect & Claude Cohen-Tannoudji
Cambridge University Press: 2002. 214 pp. £60, $90 (hbk); £19.95, $30 (pbk)

Bose–Einstein Condensation in Dilute Gases
by C. J. Pethick & H. Smith
Cambridge University Press: 2001. 414 pp. £70, $110 (hbk); £27.95, $40 (pbk)

Keith Burnett

Laser cooling uses light fields to remove kinetic energy from atoms in the gas phase through the exchange of momentum between the light fields. The fact that this leads to cooling is remarkable in its own right. What is even more surprising, as was shown in pioneering work in which the authors of *Lévy Statistics and Laser Cooling* played a pivotal role, is that atoms can be made to randomly pick up then throw away the momentum gained from the field until they find themselves 'trapped' in a region of low momentum.

This process can be used to cool atoms to low temperatures (sub-microkelvin, a fraction of a degree above absolute zero) where an atom's momentum is less than that of a single photon, a technique known as sub-recoil laser cooling. This method of laser-cooling atoms, known as velocity-selective coherent population trapping (VSCPT), means that atoms can be cooled to close to the conditions for producing Bose–Einstein condensates. These condensates are unique sources of coherent matter waves and are opening up new avenues of research in physics, as discussed in the second book. But more of that later.

Laser cooling has led to a broad range of new theories and experiments, as well as the 1997 Nobel Prize in Physics for Claude Cohen-Tannoudji, one of the authors of this book. The crucial issue, from the point of view of the book, is the extraordinary utility of the method of Lévy statistics for qualitative and quantitative understanding of laser cooling based on VSCPT. The authors have provided an excellent and readable account that will be of considerable use not only to people interested in laser cooling, but also to those wishing to see this important set of techniques make an impact in studies of ultracold matter.

The authors first give a brief explanation of the methods of laser cooling, with the details of the link between the physics and the models discussed in the book being partly relegated to an appendix to avoid breaking the flow of the text. They then show how the process calls out for a statistical method that can handle broad distributions. Lévy statistics, which is also used in many other fields including biology, Earth sciences and finance, fits the bill. This statistical method is described in just the right amount of detail for the reader to appreciate its use in laser-cooling theory. The application of the general concepts to the problem at hand is then given in clear and convincing terms, supported by a solid, physically based discussion of what is going on. The book then gives more specifics of the results, which will be used eagerly by other workers in the field. This includes, most importantly, methods for optimizing the cooling produced for various systems that can be used in the laboratory.

The book is a significant addition to the literature in both laser cooling and statistical physics. It is rare to have such a lucid and convincing account of a technique that will be new to most scientists. It will be greatly welcomed both by workers in the field of ultracold atom physics and by those who want to see an important theoretical apparatus used in practice.

One of the most exciting applications of laser cooling is the production of atoms that are sufficiently cold and dense to be evaporatively cooled to produce Bose–Einstein condensation. The laser-cooled atoms are trapped using magnetic fields and cooled by evaporation of the more energetic atoms. *Bose–Einstein Condensation in Dilute Gases* is an excellent and much-needed text of the theory of these condensates.

In a condensate, all the atoms in a gas share exactly the same de Broglie wave. In this sense they constitute giant quantum waves, in which the wave nature of matter

Look back in amber

Republished in English for the first time, the *Atlas of Plants and Animals in Baltic Amber* by Wolfgang Weitschat and Wilfried Wichard (Friedrich Pfeil, 75 euros, $98) is a rich catalogue of the flora and fauna that have been preserved in Baltic amber. It guides us through the history and geography of petrified resin and discusses the geology of amber. This spider is one hundreds of life-forms captured in amber that illustrate the book.

is writ large as the wavefunctions approach macroscopic, millimetre size. One can also think of condensates as being laser-like sources of matter waves, all the atoms having the same wave nature and state of motion. They are coherent matter wave sources or 'atom lasers' in the same sense that ordinary lasers are coherent sources of light wave photons. Because of these unique properties as macroscopic quantum systems, they are finding applications in such diverse areas of science as superfluidity, quantum computing and precision measurements based on atom interferometry.

Bose–Einstein condensates were first formed in the laboratory in 1995 by using evaporative cooling of gases to temperatures in the nanokelvin range. This work opened the door to a wide range of new physics. The pace of advances has been quite breathtaking, with studies of the physical properties of the condensates and, most recently, the prospect of their use in quantum-computational schemes. The 2001 Nobel Prize was awarded to Carl Wieman, Eric Cornell and Wolfgang Ketterle for their spectacular achievements in this field. Although progress continues at a cracking pace, there is now a set of basic notions that it is sensible to teach postgraduates, including the way that condensates are made and their physical properties as macroscopic quantum systems. This book is an excellent source of information on this topic, and is accessible to a wide range of physicists and chemists.

Previous accounts of Bose–Einstein condensation are scattered among various papers and review articles. Older texts that deal with the physics of Bose gases or superfluids cover some of the issues but deal with matters that are relevant to the new experimental scene in a cursory manner. So this is a most welcome text for those of us wishing to expound the new physics to a younger generation of physicists. The range of topics and level of detail is well matched to the needs of someone with little background in atomic or optical physics. Topics covered include the microscopic theory of trapped condensates and their superfluid properties, excitations and vortices. The authors have also included problems at the end of each chapter, enhancing the book's value as a teaching aid.

It is inevitable in such a rapidly moving field that the book does not contain information on the most recent advances concerning Bose–Einstein condensation in lattices, quantum phase transitions and quantum information processing (for reviews see *Nature* **416,** 205–246; 2002). These will probably be in the next edition of what is likely to be a best seller in its category. This well-produced book is a 'must buy' for anyone wanting to get started in this field. ■

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Science in culture

Projecting an image

Did the Old Masters paint using optical projection techniques?

Michael John Gorman

Painters from Jan van Eyck to Jean-Auguste-Dominique Ingres may have achieved a remarkable imitation of nature not through sheer painterly talent, but by using optical devices, according to David Hockney's controversial recent book *Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters* (Penguin Putnam, 2001). Specifically, Hockney, assisted by optical scientist Charles Falco of the University of Arizona, argues that from around 1430 many painters used a concave mirror to project brightly lit subjects onto a canvas, allowing them to render figures with unprecedented naturalism. Later, at around the end of the sixteenth century, according to Hockney and Falco, painters including Caravaggio began to use refractive lenses instead of concave mirrors to project their images for tracing (see *Nature* **412,** 860; 2001).

Since the publication of Hockney's provocative thesis, several objections have been raised. For example, it has been claimed that Hockney's projection technique would have required a mirror of very long focal length to create an image suitable for tracing, and that this would exceeded the technical capabilities of Renaissance mirror-makers.

New evidence concerning the history of optical projection further challenges Hockney's hypothesis. In particular, a close reading of the historical documents suggests that the specific device that Hockney and Falco claim was used widely by artists from the 1430s was in fact invented by the Neapolitan magician Giambattista della Porta in 1558, and then rendered obsolete by della Porta himself in 1589.

Della Porta was as famous for his investigations of arcane natural processes and mechanical contrivances as for being a playwright and impresario. One of the many instruments that intrigued him was the camera obscura — the generic name given to the projection of inverted images through a small hole into a darkened chamber. In 1558, he gave the earliest description of a new type of camera obscura in the first edition of his widely read book *Natural Magic*. The new technique involved using a concave mirror to project an inverted image onto a piece of paper. This is the first documented account of the device that Hockney and Falco claim was used by artists from the 1430s.

Incidentally, the first account of incorporating a convex lens into the camera obscura dates from just eight years earlier, in the encyclopedic work of the astrologer and mathematician Girolamo Cardano called *On Subtlety*, which also describes in detail the workshop techniques of contemporary painters.

ARALDO DE LUCA/CORBIS

Caravaggio may have used della Porta's camera obscura when painting *The Calling of St Matthew*.

In the expanded second edition of *Natural Magic*, published in 1589, della Porta added a dramatic revision to his concave-mirror camera obscura. As a result of his extensive investigations of optical instrumentation on the Venetian glass-making island of Murano in 1580, he combined a convex lens with the concave-mirror projection system. The remarkable result was a device that projected large, upright images. The inverted image formed by the lens, falling a short distance in front of the focal point of the concave mirror, served as an object for the concave mirror, which turned it upright and magnified it. In this way, even a concave mirror of short focal length, within the manufacturing capabilities of the late sixteenth century, could be used to project life-sized images into a darkened room, given an appropriate lens. Della Porta used this device, which doubled as a primitive reflecting telescope, not to paint but to project extravagant theatrical performances for aristocratic audiences seated in his darkened chambers.

Where does this leave the earlier paintings discussed in Hockney's book? At best, the device that Hockney claims was used by artists from the 1430s had perhaps a 35-year working life as an artist's instrument over 100 years later, assuming that it was not just an amusing toy for those unable to draw, as della Porta himself suggests. If Caravaggio used a camera obscura, he would have had every opportunity to avail himself of the latest technology — della Porta's combined convex lens and concave mirror, an instrument that goes unmentioned in Hockney's book. If fifteenth-century painters ever used the camera obscura, however, then they used a simple hole in the wall: no mirror, no lens.

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http://www.stanford.edu/group/shl/eyes/hockney