Reviews

Jonathan Jones

The second quantum revolution

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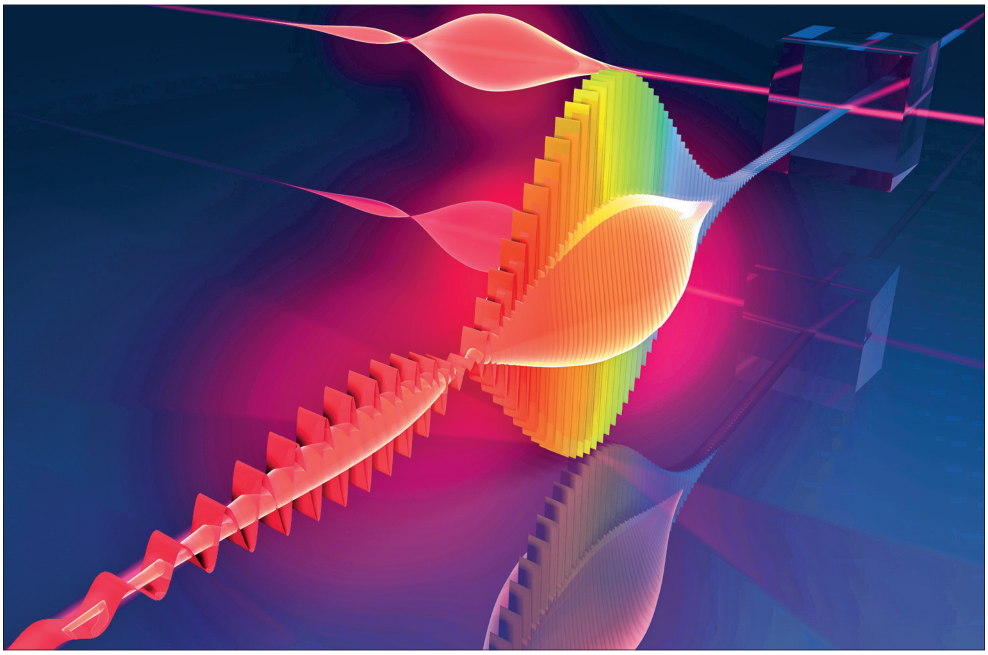

Revolutionary ideas Photon experiments form part of modern quantum mechanics.

The Quantum Divide: Why Schrödinger's Cat is Either Dead or Alive
Christopher Gerry and Kimberley Bruno
2013 Oxford University Press
£25.00/$44.95hb
208pp

The first quantum revolution was a revolution in atomic and subatomic physics, and it brought us not only the iPad and the Higgs boson but also a range of excellent popular-science books. While the atomic wonderland of the "Mr Tompkins" books now seems dated, George Gamow's images of gazelles being diffracted by bamboo groves and cars leaking through garage walls still capture vividly the strangeness of the micro world.

The second quantum revolution, in which quantum mechanics was applied first to information theory and then to information technology, is harder to popularize. This is not because quantum information processing is particularly complex but because there are no simple images that will carry you any distance into the field. To understand quantum information is to understand the mathematics describing it; without the mathematics you can have only the haziest picture of what the field is all about.

Fortunately, the crucial mathematics is quite simple and with a few basic results you can make enormous progress. In *The Quantum Divide*, Christopher Gerry, a theoretical physicist, and Kimberley Bruno, a school teacher and vice principal, have done an impressive job in cutting the necessary mathematics down to the absolute minimum, below what I previously thought was possible. While the proverbial "educated layman" might struggle at times, many readers of *Physics World* will have little difficulty; anyone who has completed the first year of a physics degree will have more than enough background knowledge to understand the book.

Bell's theorem is perhaps the founding result of quantum information theory, although the field did not blossom into its current form until many years after John Bell formulated it. In essence, Bell showed that any local realistic theory about how the world works is inconsistent with quantum mechanics. Here "local" means obeying relativity and in particular the requirement that information cannot travel faster than light, while "realistic" means that the results of measurements implicitly exist in the world before the measurements are made, with the measurement acting simply to reveal these pre-existing results. Einstein was unhappy with the ideas that eventually led to this theorem, not just because of the challenge to locality but also because of the apparent implication that observations, in effect, create the world. Unfortunately for Einstein, subsequent experiments have confirmed Bell's predictions.

In its traditional form, Bell's theorem is subtle and its derivation quite hard to follow. Gerry and Bruno have sidestepped this by describing a later variant that was invented by Lucien Hardy, developed by Thomas Jordan and subsequently popularized by David Mermin. This version begins with four statements about the outcomes of four possible sets of measurements that could be performed on a pair of particles. These four statements, if taken together, are contradictory: any three of them can be true, but it is easy to show that it is impossible for all four statements to be simultaneously true if measurements are simply revealing a pre-existing reality. It is, however, straightforward to design a quantum mechanical situation in which all four statements are true, thus immediately ruling out any naive description of the quantum world.

Gerry and Bruno carefully describe Hardy's argument in a particularly simple way, allowing the reader to see how the result can be worked out. Not all of their explanations are equally successful; in particular, I found the discussion of apparent faster-than-light communication in quantum tunnelling unclear. Overall, however, they have done an excellent job.

An unusual feature of *The Quantum Divide* is that the authors do not content themselves with theory but always describe relatively simple experiments that demonstrate the expected behaviour. These experiments are taken from quantum optics – the study of light and its interactions with matter at the fundamental single-particle level – reflecting Gerry's research in theoretical quantum optics and his textbook, published jointly with Peter Knight, in the same field. While some of the experiments are subtle and difficult to understand, others are entirely straightforward. Concentrating on this single field allows the reader to gradually build up an understanding of the experimental methods, and therefore to puzzle through the trickier scenarios.

The use of light in these experiments can, at first sight, make the results seem less surprising than they really are. The result of overlapping light waves from two sources – leading to constructive and destructive interference – is studied at school and many quantum information experiments are, in effect, little more than exotic interference effects. This view, however, misses the point: the behaviour of single photons provides a far better conceptual model for the reality underlying the physical world than the behaviour of single billiard balls or other large objects that are commonly used as examples. The debate as to whether objects are really particles or really waves is fundamentally sterile: in fact, they are really just like light.

This leads, of course, to the philosophical problems of quantum mechanics – one of which is apparently answered up front by the book's subtitle, *Why Schrödinger's Cat is Either Dead or Alive*. Gerry and Bruno cheerfully adopt a relatively standard Copenhagen interpretation of quantum mechanics for most of the book. In this approach, sometimes called a "psi-epistemic" view (see "The life of psi", May pp26–31), quantum mechanics says nothing about how the world really is but only describes what we can know about it. Since I have learnt about quantum information in a many-worlds, "psi-ontic" community, in which the quantum state is considered to be the true reality, this approach seems odd to me and I am not certain whether the authors completely believe their own public view.

However, as they make clear, these philosophical questions determine only how we think about the experiments we perform and in practice all of the different interpretations make the same predictions for any experiment we can imagine performing at the present time. Can we really say whether Schrödinger's cat *is* alive and dead at the same time? It is hard to beat Bill Clinton's reply made in a different context: that depends on what the meaning of the word *is* is.

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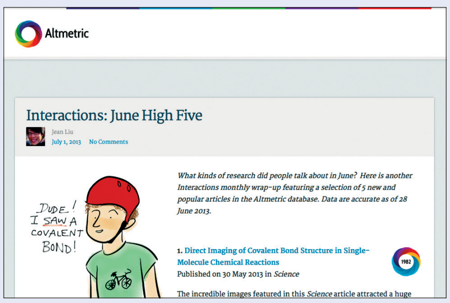
Web life: Altmetric blog



URL: www.altmetric.com/blog

So what is the site about?

Altmetric is a London-based start-up firm specializing in "alternative article-level metrics". Unlike more traditional ways of gauging the importance of a scientific paper, such as counting the number of citations or looking at the reputation of the journal that published it, alternative metrics attempt to measure a paper's impact using factors such as the number of blog posts about the paper and the number of times that it gets mentioned on *Twitter* and other social media. Altmetric's blog, like many run by commercial firms, is partly geared towards advertising the company's own products, which include a numerical "score" that reflects how often a paper has been discussed in the publications, blogs and social-media sites that Altmetric monitors. However, the blog also covers more general issues surrounding the emerging field of altmetrics and the related open access movement in scholarly publishing (see pp22–27). Some posts, for example, offer case studies on ways that particular papers have been shared via social media or discuss the type of information that next-generation altmetrics might offer.

What if I don't care whether my papers are popular on *Twitter* or not?

In that case, you are either less shallow than most people or you are already so well known that you have become blasé about publicity. Congratulations. However, there are reasons other than vanity for wanting to quantify other people's responses to your work. Citations and a journal's impact factor are still important barometers, of course, and the online versions of some journals (including many of those produced by IOP Publishing, which also publishes *Physics World*) have also started to provide additional data on how many people have downloaded papers or bookmarked them using online reference managers such as Mendeley and CiteULike. However, funding organizations increasingly want to know how a grant applicant's work is affecting people outside the research community as well as in it. Think about the last scientific paper you wrote. How many people read it? What did they think of it? Did they share it with their colleagues? Their friends? Journalists? If you can demonstrate that, say, 14 people, including two journalists, found your last paper interesting enough to blog about, while 23 others passed it on to their *Twitter* followers, it might just tip the balance in your favour the next time you find yourself applying for funding.

That could be useful – but who's behind it?

Altmetric was founded in 2011 by Euan Adie, a former medical geneticist who had previously worked on online research tools at Nature. Later that year the firm won start-up funding in a competition run by the publishing giant Elsevier and it has subsequently received support from Digital Science, which (like Nature) is part of the Macmillan group of publishers. The editor of the blog, Jean Liu, has a background in neuroscience and also writes a personal blog called *The Portable Brain*.

Can you give me a sample quote?

From a post about the altmetrics of a paper on bio-inspired dynamical surfaces: "These special surfaces, which were inspired by the sweeping motions of motile cilia, were created by applying a novel material that has the ability to repel bacteria that make up biofilms. It works like this: some kind of stimulus (e.g. electrical voltage, mechanical stretching or air pressure) is applied to the material, deforming the surface and dislodging any biofilms that are attached. The practical applications are immense: notably, the material could be painted on the hulls of ships, then used to stop "biofouling" by the easy removal of accumulated gunk (biofilms and barnacles).

For a paper with such useful applications (biofouling is a huge problem for mariners), how can one define the outcomes that would constitute impact? Even after more development and rigorous testing takes place, it may take years for the new technology to be adopted by shipbuilders. And so, for the time being, we should try to look for more immediate indicators of academic and online impact … altmetrics can be excellent early indicators of research uptake in society."