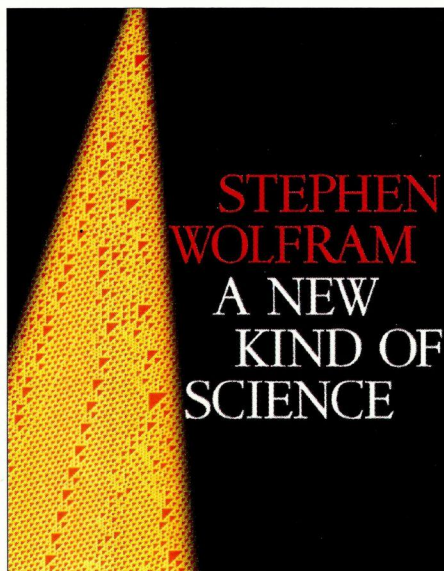


BOOKSHELF

A New Kind of Science by Stephen Wolfram, Wolfram Media, Inc. ISBN 1579550088, \$44.95 (US); £40 (UK).

"Three centuries ago, science was transformed by the dramatic new idea that rules based on mathematical equations could be used to describe the natural world. My purpose in this book is to initiate another such transformation, and to introduce a new kind of science that is based on the much more general type of rules that can be embodied in simple computer programs." Thus begins *A New Kind of Science*, in a probably self-conscious reference to Newton's *Principia*. Ambition is certainly not lacking; this work claims to give us a radically new view of a large number of natural and social sciences. The author says that the discoveries he has made with his new kind of science will transform many fields of scientific endeavour, including the theory of evolution; the interpretation of genetic information; the origin of morphology in biological systems; embryology; the very notions of space and time; elementary particles; quantum mechanics; a fully fledged complexity theory; and brain function. A deeper understanding of things like free will and extraterrestrial intelligence are thrown in for good measure.

Wolfram was a child prodigy who also worked on particle physics and cosmology, making important contributions. He is well known as the author of *Mathematica*, a magnificent software package that allows sophisticated symbolic manipulations. This provides the basic tool for the investigations presented in this volume. When the program was released, it was an instant success, and most high-energy physicists are almost as addicted to it as they are to Paul Ginsparg's archives. Nearly 20 years ago, Wolfram decided to study systems known as cellular automata. The simplest of these consists of an array of cells that can be in two states – say black and white – whose evolution generates a pattern in a two-dimensional array. The update rule that allows us to determine the state in the next row is (in the simplest variety) determined by the state of the cell and that of its two nearest neighbours. In this case the total number of possible rules is just 256, and one can program a computer to study their evolution for a variety of initial conditions. A particularly important program is rule 110, which states that if the cell is white, it will only turn black if its right neighbour is



black, and if it is black, it will remain black unless its two neighbours are also black, in which case it will turn white. Given the initial condition, one can apply the rule and follow the two-dimensional pattern that is generated after many iterations. Wolfram discovered in the early 1980s that in spite of the simplicity of these rules, the patterns generated can contain great complexity – simple rules can generate complex behaviour. By thoroughly studying many kinds of cellular automata, he proposed their classification into four categories according to the long-term patterns they generate: uniformity, periodicity in time, fractals, and genuine complex non-repetitive patterns. With this principle, he begins his study of how to understand the complexity we observe in nature.

After making the basic observation by looking at computer experiments with linear cellular automata, Wolfram presents many other systems leading to complex behaviour, including higher-dimensional cellular automata, tag-systems, substitution systems, continuous automata and Turing machines. His conclusions always seem to be that once complex behaviour is achieved, the addition of new rules (complicating the initial program) will not significantly change the level of complexity. He also presents a plethora of natural phenomena that at first sight look complex. Traditional intuition might lead to the belief that the underlying rules are complicated, but Wolfram can produce simple automaton rules that visually reproduce their pattern of complexity. This includes snowflakes, leaves in

plants, mollusc shells, iterated maps, pigmentation patterns throughout the animal world, the breaking of materials, earthquake patterns, and many others. Some of these phenomena have been studied by others, but since the main body does not include references, it is hard for the reader to know this.

In some instances, Wolfram's case is convincing; in others it looks more like a good guess. In chapter 9, for example, he offers his view of the origin and exceptions of the second law of thermodynamics, together with a speculative model of the physical universe based on discrete causal networks where elementary particles are identified with localized structures of the universal automaton. The model is far from being testable, and furthermore, the way in which quantum mechanics is incorporated may have difficulties with the Bell inequalities.

The last two chapters on the notion of computations and the principle of computational equivalence are the natural conclusion of previous arguments. Like others (in particular Edward Fredkin), Wolfram proposes that the universe is a computation ("it for bit", as John Wheeler would say). The fact that running simple programs roughly reproduces a large variety of complex patterns leads him to formulate his principle of computational equivalence (p720): "The principle of computational equivalence introduces a new law of nature to the effect that no system can ever carry out explicit computations that are more sophisticated than those carried out by systems like cellular automata and Turing machines." In fact, in chapter 11 a proof is presented showing that rule 110 is a universal Turing machine – a universal computer. On p115 we learn that the proof comes from one of Wolfram's former employees, Matthew Cook, who was asked to work on it by Wolfram himself. The fact remains that to codify other universal computers as initial conditions to rule 110 so that it can simulate them seems extraordinarily complicated. Assuming the proof to be correct, and Wolfram is aware that a few errors may remain, it provides the simplest universal Turing machine constructed to date. However, a more unsettling conclusion can be drawn. Since humans are more processes than beings (we are gene survival kits, as Richard Dawkins colourfully puts it), we can describe our existence as an ongoing computation. Hence according to the principle of computational equivalence, we are ▶

computationally equivalent to rule 110. Ever since Copernicus, our place in the universe has diminished. Wolfram's conclusion seems the epitome of Copernican recession. "But the Principle of Computational Equivalence also implies that the same is ultimately true of our whole universe," Wolfram reassures us on p845. The problem may also be in the details of the initial conditions, and the devil is always in the detail.

If we follow the previous arguments, the same principle seems to lead inevitably to the conclusion that the whole universe, with all its subtle and wonderful features, can be encapsulated in a few lines of computer code (for example in *Mathematica*). The book ends with a humbling thought: "And indeed in the end the Principle of Computational Equivalence

encapsulates both the ultimate power and the ultimate weakness of science. For it implies that all the wonders of our universe can in effect be captured by simple rules, yet it shows that there can be no way to know all the consequences of these rules, except in effect just to watch and see how they unfold."

Wolfram has very high expectations for his new kind of science. No doubt many of his ideas and analyses will be incorporated in scientific discourse, but whether they will have the power to truly solve basic open questions in so many fields of knowledge (even in just one would be a great accomplishment) remains to be seen.

The book is often vague, which is in part due to the style of exposition chosen by the author, who is writing for a general audience. In (tradi-

tional) scientific practice, the identification of precise definitions and features of a given problem often takes us a long way towards its resolution. It is clear that much more work will be done following the methods of this book, and in a few years' time, we will know whether they have become commonplace.

Apart from the controversial and speculative aspects of this book, it is worth mentioning that it provides an excellent expository account of large areas of physics, mathematics, computer science and biology in the main text and in the notes. The latter contain lucid presentations of vast areas of human knowledge. There is a lot to be learned from this book, and without a shadow of doubt, it will not leave you indifferent.

Luis Alvarez-Gaume, CERN.

LETTERS

CERN Courier welcomes feedback but reserves the right to edit letters. Please email cern.courier@cern.ch.

Particle physics in New Zealand

You described a plan for New Zealand to contribute to instrumentation for the LHC that is being built primarily to search for the Higgs boson (*CERN Courier* August 2002 p29). It might have been mentioned that not all New Zealanders believe in the existence of the Higgs boson, even though some basic concepts of the Standard Model were proposed here. The profile did of course refer to Rutherford, although he may not have done much nuclear physics in New Zealand. It is, however, perhaps noteworthy that astronomers in New Zealand are currently using a gravitational microlensing technique that is comparable to Rutherford scattering to search for terrestrial extra-solar planets. The main difference is that whereas in Rutherford scattering electrons decelerate the projectile, in gravitational microlensing, the projectile is deflected by planets. The mathematics is otherwise quite similar.

Philip Yock, University of Auckland, New Zealand.

Alick MacPherson replies:

It was with great pleasure that we were able to report in *CERN Courier* the development of a New Zealand particle physics initiative that will contribute to the CMS pixel detector and the CMS heavy-ion programme. By design, NZ_CMS (now elected a full member of CMS)

will contribute to CMS, while building on existing research strengths within New Zealand physics research (astro-particle physics, astronomy, electronics, materials science and solid state). It is expected that NZ_CMS will foster developments with the wider research community, the New Zealand government and industrial sector, which will benefit both New Zealand and CMS.

In short, a crucial factor in the success of NZ_CMS will be its ability to develop synergies within the New Zealand research community, and to extend these through the strengthening of international links. As such, we see it as a healthy sign that New Zealand physicists are not in uniform agreement on the structure of our underlying particle theory, and that the NZ_CMS programme has renewed interest amongst New Zealand researchers and students in high-energy particle physics. Indeed in the last year, guided visits to CERN and to the CMS experiment by New Zealand-based staff and students have been made on five occasions, compared with none in the previous year.

The NZ_CMS programme, with a combined thrust of fundamental HEP and instrumentation technology, should create a strong and well-balanced New Zealand-based particle physics research initiative that builds on our existing strengths, while opening research, technology and industrial opportunities for young New Zealanders. This will allow New Zealanders to develop and participate fully in CMS, without adding to the "brain drain" of human resources that has plagued New Zealand since the time of Rutherford.

Growing internationalism at Fermilab

I enjoyed your piece on Fermilab (*CERN Courier* November 2002, p32), but unfortunately, a small error crept into your description of D0's evolution. The French Saclay laboratory was indeed the only non-US founding member of D0, but this happened in 1984 (not 1996). By 1995, the author list on the top quark discovery paper had grown to include groups from Brazil, Colombia, France, India, Korea, Mexico and Russia, together with visitors from Argentina, China and Ecuador, who later went on to become the nuclei of full member groups in those countries. Now the list of countries affiliated with D0 also includes the Czech Republic, Germany, Ireland, the Netherlands, Sweden, the UK and Vietnam. Western European involvement is substantial – instead of one French member group, we now have seven. More than half of our collaborators are now from non-US institutions.

John Womersley, co-spokesman, D0 experiment.

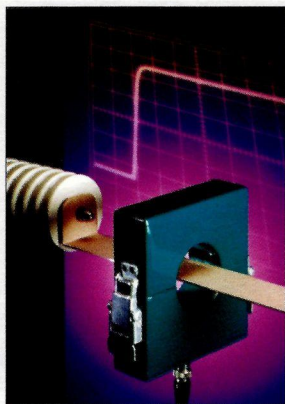
Comment:

The internationalization of D0 has indeed been impressive, reflecting a growing trend in particle physics in general. From one foreign institution to over 50% non-US participation in two decades is certainly substantial, and CERN is undergoing a similar evolution, with over 40% of collaborating institutes being in non-member states.

Another error crept into the profile. The Tevatron is, of course, a proton-antiproton collider, and not a proton-proton machine.

James Gillies.

SUPPLIER INFORMATION



Pearson Electronics Inc

Fast wide-band current monitors

Pearson Electronics is the original and leading manufacturer of wide-band current monitors. Pearson monitors measure submilliamp currents of up to several hundred thousand amps. New fast designs have a 3 dB bandwidth from 140 Hz to 250 MHz and a rise time of 1.5 ns. Clamp-on current monitors and standard models are in stock and available for immediate delivery.

Pearson Electronics Inc
4009 Transport Street, Palo Alto, CA 94303, USA
Tel: +1 650 494 6444
Fax: +1 650 494 6716
Web: www.pearsonelectronics.com



VAT Vacuum Products Ltd

The VAT Series 54 all-metal right-angle valve

A new concept in all-metal sealing technology! The traditional copper pad system is replaced with a stainless-steel Vatrang. The valve closes to a physical stop, eliminating the need to even consider closing torque. Any operator can close the valve leak-tight every time.

VAT Vacuum Products Ltd
Edmund House, Rugby Road, Leamington Spa,
Warwickshire CV32 6EL, UK
Tel: +44 (0)1926 452 753
Fax: +44 (0)1926 452 758
E-mail: uk@vatvalve.com
Web: <http://www.vatvalve.com>

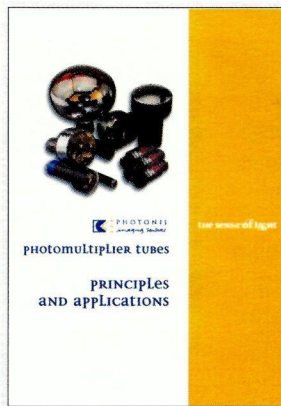


Janis Research Company Inc

Janis offers APD cryogenics 10 K cryocoolers

Janis is pleased to announce that the original APD cryogenics pneumatically driven, 10 K cryocoolers are once again available. These cryocoolers are supplied with either Janis cryostats or as "bare" systems, and are provided in either the DE-202 or DE-204SL configurations. A complete range of accessories and ancillary equipment are available.

Janis Research Company Inc, 2 Jewel Drive,
Wilmington, MA 01887 USA
Tel: +1 978 657 8750
Fax: +1 978 658 0349
E-mail: sales@janis.com
Web: www.janis.com



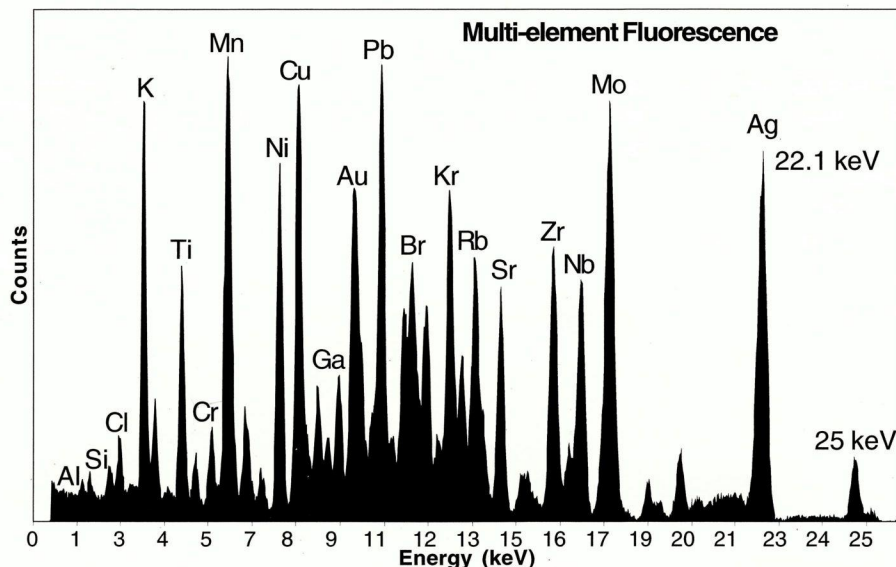
Photonis

Photonis, based in Brive, France, a world leader in PMT development and manufacture, offers you a free copy of the new edition of our 320-page book *Photomultiplier Tubes - Principles and Applications*. The book, which was originally published when Photonis traded as a division of Philips Photonics, is a popular reference with scientists and engineers and is particularly suitable as lecture material for introductory courses in nuclear-detector technology. For your free copy, please contact:

Carole Marmonier, Photonis,
BP 520 F-19106, Brive, France
E-mail: c.marmonier@photonis.com
See also our updated website www.photonis.com.

X-Ray Detector

XR-100CR at 186 FWHM Resolution



No Liquid Nitrogen!!!

Solid State Design

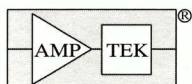
APPLICATIONS

- Nuclear Physics
- Synchrotron Radiation
- High Energy Physics
- Neutron Experiments
- Astrophysics
- Research & Teaching
- Nuclear Medicine
- X-Ray Fluorescence

Easy - simple to operate and portable

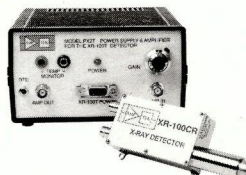
Performance - approaching that of Si(Li) detectors

Affordable - visit www.amptek.com



AMPTEK Inc.

6 De Angelo Drive, Bedford, MA 01730-2204 USA
Tel: +1 (781) 275-2242 Fax: +1 (781) 275-3470
E-mail: sales@amptek.com www.amptek.com



XR100CR X-Ray Detector
with Power Supply &
Amplifier



XR100CR fitted for vacuum
applications