will; while what could be more impersonal than the block Universe, in which our entire existence is some almost insignificant thread?

Indeed, it seems to me that the main thesis of *The Matter Myth* rests on an ambiguity in the notions of materialism and mechanism. These terms are sometimes used in contrast to humanism or idealism, and sometimes with reference to a specific (say, newtonian) conception of the fundamental nature of the world. These two senses are somewhat mixed up when Davies and Gribbin describe mechanism as "the belief that the physical Universe is nothing but a collection of material particles in interaction, a gigantic purposeless machine, of which the human body and brain are unimportant and insignificant parts". Provided that we keep the senses distinct, it is possible to see that a world view may be materialist in the first sense — that is, impersonal — without being newtonian. And that, surely, is what the physics of the past century has given us. (Lest it be suggested that I have ignored genuinely recent developments concerning chaos and nonlinearity, what comfort is it if it turns out that we and our Universe are *unpredictable* machines? Is a rogue robot any more human than its predictably programmed cousin?)

Leaving aside its claims concerning materialism, there is a lot to recommend the book. Davies and Gribbin are both masters of the art of describing complex scientific ideas to lay audiences, and in this respect they maintain their usual high standards. So read it for this, but take the news of the revolution with a pinch of salt.

One of the great challenges of the popular science genre is to be entertaining as well as intellectually stimulating. A writer who does well in this respect is Timothy Ferris, whose *The Mind's Sky* is an enjoyable ramble through a variety of topics to do with minds, brains and their place in the cosmos. I particularly liked the suggestion that there might already be a self-extending information network, spreading the accumulated knowledge of diverse civilizations through the galaxy. Let us hope that when we find our local terminal it is in working order. (How frustrating to have to wait 10,000 years for the Repair-Creature.)

By contrast, *The Capricious Cosmos* is a salutary example of the dangers of venturing into print beyond one's field. The basic guidelines here are those of foreign travel: try to pick up a smattering of the language, and tread lightly. This book is a physicist's journey into metaphysics, but fails on both counts. □

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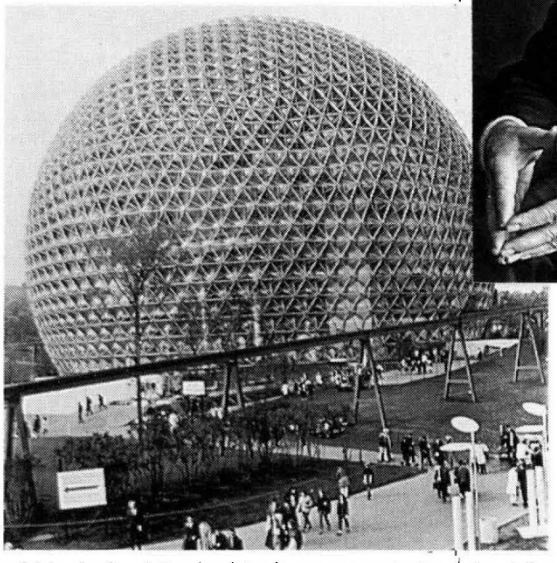
From brilliance to crackpottery

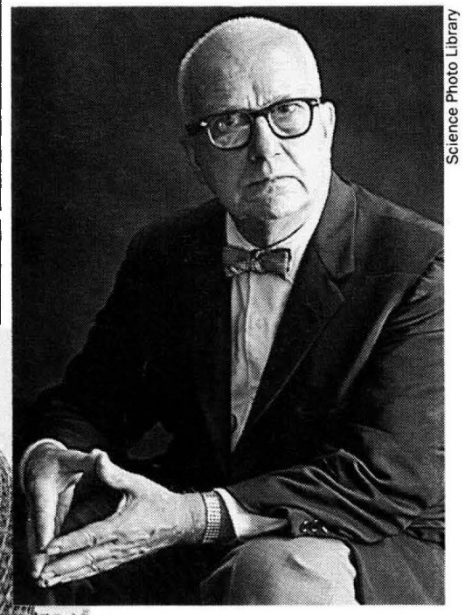
Ian Stewart

Cosmography: A Posthumous Scenario for the Future of Humanity. By R. Buckminster Fuller (adjuvant: Kiyoshi Kuromiya). *Macmillan, Inc. (USA): 1992. Pp. 277. $24.95.*

AT a time when a 60-atom carbon cage named in honour of an architect has boldly been hailed by *Science* as "molecule of the year", a book on the working philosophy of the man himself would seem only appropriate. That the molecule should be called "buckminsterfullerene' rather than 'truncatedicosahedrene' reflects the extent to which Buckminster Fuller succeeded in putting his ideas across to humanity. But not every innovation for which he tends to be given credit is as original as his admirers imagine.

In 1983, on the day that Buckminster Fuller died, the manuscript of *Cosmography* was found stacked in the middle of his desk. Attached to it was a note to his daughter and grandchildren, stressing "the extraordinary importance of my now being written book". Kiyoshi Kuromiya, the "adjuvant", a term that Fuller borrowed from medicine, has sensibly preserved the author's "idiosyncratic concepts, tone, syntax, and phraseology". As a result, we have a book that lets its readers get inside that extraordinary — and rather frustrating — mind.





Science Photo Library

Buckminster Fuller and the glass geodesic dome that he designed for the US pavilion at EXPO '67 in Montreal, Canada.

Fuller saw the human race as still living in the Dark Ages, locked into a futile circle of misinformation, perverted by big business, militarism and organized religion. He sought the rebirth of humanity in a better future, a world in which individual genius would be nurtured rather than suppressed. This philosophy led him to conduct his life as an "experiment in individual initiative". It led to some remarkable achievements, most notably the invention of the geodesic dome. It led him to formulate the idea of "synergetics", in which objects are replaced by systems, balanced between their internal and external features. And it led him to make scathing but rather generalized criticism of conventional science. All of this was laced with a characteristic obsession with numerology and an uncompromising view of the importance of truth.

Cosmography reveals the astonishing strengths of Fuller's mind, as well as its flaws. One cannot doubt the sincerity of his vision of the human predicament, nor fault many of his insights: "Big money, big religion, and big politics are all still deliberately frustrating human comprehension"; or, as my father once said to me, "they teach you enough to take orders, but not to give them." Equally, it is hard to agree that *every* child is born a genius. With more than 200,000 geodesic domes in existence, one can hardly quibble over Fuller's success and originality as an architect. But what about his claim that stacks of cubical boxes tend to separate as they grow higher because local verticals are not parallel on a spherical Earth? To Fuller this is important, representing yet another nail in the coffin of the "misinformed XYZ" coordinate system beloved by physicists. To me, and to physicists, it shows that Fuller can't do a back-of-the-envelope calculation. Except that he can — when he wants to. His geometric ingenuity is striking. Who else would have noticed that you can fold up

four circles and assemble them to form a cuboctahedron (what he calls "vector equilibrium")? On the other hand, who else would see a cryptic, mystic message in such a possibility?

Far sadder is his tendency towards numerology, and the belief that on such a basis he could think his way towards an understanding of the fundamental structure of the Universe. "This 28 we multiply by the twoness of internal mite rearrangeability of the mite's 2 A and 1 B modules, giving us 56 arrangements of the same total energies inter-energy-proclivities of each coupler". After pages like this we are told that "synergetics provides. . . a more sophisticated understanding of subatomics than that of the nuclear physicist whose favourite tool is the atom-smasher."

It is this kind of lurch from brilliance to crackpottery that makes Fuller so infuriating. He is far more convincing when he avoids specifics. The defects of his numerology are obvious, but he still has a valid viewpoint when he suggests that smashing atoms to bits may not be the cleverest way to decide how they work. Reductionist biologists, just as obsessed with the DNA code as is Fuller with his numerology, would do well to heed his warning that "nature invents many alternative circuits that provide the same results"; and to take on board the principle that outsides matter just as much as insides. And we should all think long and hard about the failures of "traditional human power structures and their reign of darkness". *Cosmography* builds on too many of Fuller's flaws to be a great book; but its author, flaws notwithstanding, was a great man. His book lays bare his own enigma. □

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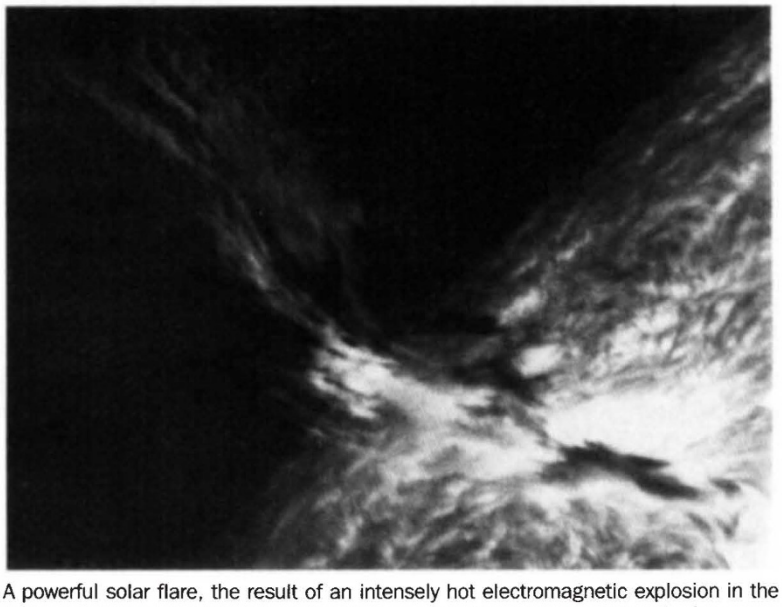
Twinkle, twinkle

David W. Hughes

Stars. By James B. Kaler. *Scientific American Library/W. H. Freeman: 1992. Pp. 274. $32.95, £17.95.*

THERE are three great problems when it comes to studying stars. Most stars are a long way off and, with the exception of the Sun, they are perceived as little more than points of light. So we know the detailed vagaries and variabilities of only one stellar surface, and that has been studied for only a couple of centuries. Stars are huge turbulent spinning spheres of glowing gas energized by intense nuclear reactions in their deep interiors. But the radiation that we can detect comes only from an outer layer a thousand or so kilometres thick. The remaining 99 per cent of the stellar volume is beyond our ken and can be probed only by the theoretical extrapolation of physical equations. And the pace of stellar evolution is so slow that astronomers rarely see an individual star age. Our understanding of the life-cycle of a star has to come from glimpsing a host of different ones during their baby, youthful, middle-aged and geriatric periods.

Coupled with these stellar problems are a series of traps set for people who write about the stars, traps that seem to originate from the time-honoured and rather dreary order in which most astronomy textbooks approach the subject. James Kaler unfortunately falls headlong into these traps. The first 60 pages of his book regale the reader with risings and settings, celestial poles and meridians and telescopic mirrors and detector designs. Only after ploughing through this overly long introduction does one start to get some feeling for what a star actually is. But even then the true picture has to await a discussion of black-body radiation and atomic spectroscopy. At last, by about page 85, the reader begins to realize that stars are not all the same but have luminosities that range from a million times brighter than the Sun to a million times fainter, masses that range from 120 to 1/13 solar masses, and sizes that range from a few kilometres to the size of the orbit of Saturn.



A powerful solar flare, the result of an intensely hot electromagnetic explosion in the corona, produces vast quantities of X-rays which brighten the chromospheric gases.

I greatly enjoyed the section of the book dedicated to stellar interiors, and Kaler has done a first-rate job of explaining the complexities of stellar energy generation and transportation. But I was a bit surprised that he then proceeded to tell how the Sun would evolve in the future (giant, helium flash, supergiant, planetary nebula, white dwarf and so on) before he revealed how the Sun actually came to be what it is today. I also thought that the general reader would get slightly confused by his brief explanation of the Sun's journey along the Red Giant Branch and the Asymptotic Giant Branch of the Hertzprung–Russell diagram.

Balancing those portions of the book that I would have omitted were sections that I would have expanded. I would have liked more about why the luminosity function has the form that it has, why only half the stars are binaries and how planetary formation is related to star formation?

Even though stars are the primary source of energy in the Universe, and our planet and all living things are made of stardust, I still found Kaler's statement that "to know ourselves we must know the stars" a touch pretentious. I also found my mental imagery linguistically distorted when I read that "stars come dripping from the fonts of interstellar space" and that "as they age they pump enriched matter back into the wallsprings of creation"; but after a time you get used to it. And Kaler can be forgiven, because it is clear that stars are his great love.

His enthusiasm becomes infectious. I was even able to overlook the fact that he misspelt the christian name of my hero Edmond Halley; but to state that Halley went to Cambridge rather than Oxford was going too far. I was heartened by the many times that Kaler admits that astronomers are still mystified by many aspects of stars and stellar evolution. The true joy of working at the frontier of astronomy is portrayed very well.

Stars abounds with beautiful stellar pictures and, as one would expect from a book from the *Scientific American* stable, the standard of the illustrations and figures is first class. □

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