In the beginning

Michael Rowan-Robinson

The Shadows of Creation: Dark Matter and the Structure of the Universe. By Michael Riordan and David N. Schramm. *W. H. Freeman: 1991. Pp. 278. £18.95.*

In his 1977 classic, *The First Three Minutes*, Steven Weinberg took as his starting point the moment one hundredth of a second after the Big Bang when the first stages of cosmological nucleosynthesis began. The basic features of the Big Bang model have been well understood from that point onwards for more than 20 years. The microwave background radiation, discovered by Arno Penzias and Bob Wilson in 1965, demonstrates that for the first 100,000 years of its history the Universe was dominated by radiation, the 'fireball' phase. Only when this radiation had cooled sufficiently could ordinary matter begin to respond to the gravity field generated by the ripples in the density distribution that our existence proves must have been present. This microwave radiation, responsible for at least part of the noise on our television screens when broadcasting ceases, gives us a direct image of the Universe as it was only 100,000 years after the Big Bang. But the radiation is incredibly smooth: so just how could the lumpy Universe that we see today, of which our bodies with a density 10^{30} times the average are the epitome, have arisen from such a beginning? That has been one of the key questions of the past decade.

Although the microwave background radiation represents our earliest direct measurement of the Universe, the nuclear physics of 20 years ago allowed us to extrapolate back to a time one hundredth of a second after the Big Bang. The prediction of the abundances of the light-elements, helium, deuterium and lithium, was one of the triumphs of Big Bang cosmology in the 1960s and 70s. The remarkable development of the past decade, which is brilliantly expounded in this new book, has been to push our understanding of the history of the Universe back in time a further 10^{33} times to 10^{-35} seconds after the Big Bang. Some of the ideas involved are so bizarre and outlandish as to baffle all but the most dedicated particle physicist. Yet, strikingly, they have been widely accepted by theoretical cosmologists, despite an almost complete absence of experimental confirmation.

The Shadows of Creation is a superb book, perhaps the best on a cosmological subject since *The First Three Minutes* (Basic Books), certainly, more illuminating and relevant than the fêted *Brief History of Time* (Bantam, 1988) by Stephen Hawking, who, incidentally, writes the preface to the new book. In a nutshell, its authors describe how theories for the unification of the forces of nature led first to the idea of an inflationary Universe and thence to a model of a Universe filled with some new kind of dark matter so far undiscovered. The first step along this road, the unification of the electromagnetic and weak-nuclear forces by Steven Weinberg and Abdus Salam, was powerfully vindicated with the discovery at CERN in 1983 of the W and Z gauge bosons which 'mediate' this unified electroweak force.

"THE BIG BANG? BELIEVE ME, IT WAS VERY, VERY, VERY, VERY, VERY, VERY BIG."

In modern particle physics, all forces can be thought of as being due to the exchange of a mediating particle, from the photon for the electromagnetic force to the gravitino for gravitation. Experimental confirmation of the idea that the strong nuclear force can be unified with the electroweak force has yet to be achieved, but particle physicists and theoretical cosmologists take it as read that these forces were unified before the first 10^{-35} seconds after the Big Bang. At that instant, a phase transition is believed to have occurred, which left our bit of the Universe with an immense vacuum energy density that then behaved like a huge repulsive force, suddenly inflating the Universe exponentially by a factor of 10^{50} or so. 'Inflation' solves several metaphysical cosmological problems and would be expected to leave the Universe with a density 10–100 times that of ordinary matter today. It is this 'dark matter' that is the shadow of creation.

The dark matter can also solve the problem of how gravity can make galaxies and ourselves, starting from the smooth state revealed by the microwave background radiation 100,000 years after the Big Bang. Riordan and Schramm weave us through the fascinating story of how particle physicists, cosmologists and astronomers have orbited about one another to establish a theory on the sands of the invisible and (so far) undetectable. The exposition of the nuclear physics is brilliant and will give the non-expert reader a real sense of getting to grips with the remarkable developments of the past decade. So many different theories about the nature of dark matter are presented, however, that the reader may find it hard to get a clear picture of what is believed. If 'superconducting cosmic strings' have been eliminated by recent observations, do we need to know about them in the first place? Perhaps it is a virtue, though, that the authors do not go overboard for any particular theory about the nature of dark matter.

There have been some considerable developments in cosmology since the book went to press. The galaxy redshift surveys carried out by my colleagues and myself with the Infrared Astronomical Satellite show that, on the one hand, the motion of our Galaxy through the microwave background radiation can be understood provided that the density of the Universe is indeed as high as predicted by inflationary cosmology. On the other hand, there is more structure on large scales than is predicted by one of the most popular dark-matter theories of galaxy formation, that of 'cold' dark matter. I was delighted, incidentally, by the figure on page 149 of the book showing a monster 'Great Attractor' behind the Hydra-Centaurus cluster, because when I recently announced that surveys with the Infrared Astronomical Satellite did not show this, a prominent Great Attractor supporter responded bitterly, "That [the existence of such an object] was not what I meant at all. That was not it at all."

I was surprised by the authors' implication that gravitational lenses have not yet been detected, for a few good examples have been known for several years. And dark halos of spiral galaxies stabilize the disc against the formation of a bar, not against disruption.

Well-written and excellently illustrated, this fascinating and inspiring book will give the general reader valuable insight into the way particle physicists and cosmologists are thinking today. □

Michael Rowan-Robinson is at the School of Mathematical Sciences, Queen Mary and Westfield College, Mile End Road, London E1 4NS, UK.