BOOK REVIEWS

Decaying Dark Matter

Modern Cosmology and the Dark Matter Problem. D. W. SCIAMA. Cambridge University Press, New York, 1994. xviii, 216 pp., illus. Paper, $29.95 or £17.95. Cambridge Lecture Notes in Physics, 3.

The Renaissance of General Relativity and Cosmology. A Survey to Celebrate the 65th Birthday of Dennis Sciama. GEORGE ELLIS, ANTONIO LANZA, and JOHN MILLER, Eds. Cambridge University Press, New York, 1994. x, 331 pp., illus. $49.95 or £30. From a meeting, Trieste, Italy, April 1992.

What is the universe made of? We know about some of it—the electrons and baryonic quarks that make up ordinary matter—but most of the matter of the universe is detected only by its gravity (the force that holds galaxies together) and could in principle be something else. Indeed, if the big bang picture of the early universe is correct, most of the matter is probably in some "nonbaryonic" form; otherwise the predicted abundances of the light elements would not come out right.

The big bang theory also suggests an idea of what form the nonbaryonic matter might take. The density in the hot cauldron of the early big bang was dominated by radiation, the photon component of which, cooled by the expansion of the universe to the microwave background we see today at 2.78 degrees Kelvin, is now a tiny fraction of even the baryonic density. The relic primordial radiation field left behind, in addition to the microwave background radiation, an invisible component not of radiation but of a form of nonbaryonic matter—a vast sea of elusive neutrinos, filling all of space.

Every nook and cranny of the universe, including the space filled by ordinary matter, is filled with primordial neutrinos; on average a cubic centimeter of space contains hundreds of them, a billion times more than the number of atoms contained. If it turns out that these neutrinos have a mass, even if it is very tiny, there are so many of them that they could dominate the mass density—and it would be fair to say that the universe is made mainly of neutrinos.

How can one test this hypothesis? The primordial neutrinos, though abundant inside all laboratories, interact so weakly and with so little energy that they cannot be detected directly. The distribution of cosmic dark matter offers a few clues, but these are inconclusive, as the gravity from neutrinos acts like the gravity from anything else.

On the other hand, if the neutrinos were to decay into something else, their effects might be seen much more easily. Dennis Sciama has for the past five years pursued a bold idea: not only is the universe made mostly of neutrinos, these neutrinos are slowly decaying into radiation. He has pursued this "decaying dark matter" into a tiny corner of parameter space, publishing precise values for the neutrino mass, the Hubble constant, and even the neutrino lifetime. Images showing the ghostly fluorescence of gas illuminated by a galaxy halo of neutrinos decorate the frontispiece and the cover of the two books under review here, one of them a monograph by Sciama on the DDM hypothesis and the other a festschrift in honor of his 65th birthday.

The hypothesis is particularly fascinating both for its boldness and for the connections it makes. To dominate the universe, the mass of neutrinos must be a few tens of electron volts, so that their decay creates ionizing ultraviolet radiation. If they decay fast enough, they can dominate the ionization of large regions of interstellar space. In Sciama's scheme, the ultraviolet light of neutrinos plays an important role in the astrophysics of many systems, examples including the ionization of pregalactic gas and the ionization of interstellar gas in our galaxy. Various constraints on the ionization of hydrogen and nitrogen in interstellar space then restrict the range of mass to a narrow range—$m_\nu = 29.4 \pm 0.4$ electron volts—and the lifetime to $\tau_\nu = (2 \pm 1) \times 10^{23}$ seconds, almost a million times the present age of the universe. Since the average number per volume is known from big bang theory, the mass also fixes the mean density. With the additional leap of faith that the universe is exactly flat (and why not? it is so close anyway once the mass is fixed at this value), the mean density is then precisely related to the rate of expansion, so that the Hubble constant must have the value $H_0 = 57 \pm 0.5$ km sec^{-1} Mpc^{-1}. This is certainly the most precise value for H_0 ever achieved by a serious scientific argument, all the more surprising since it involves no actual measurement of the Hubble constant or indeed even of a distance, a velocity, or an age.

In spite of its attention to the unusual DDM model, Sciama's monograph is a worthy modern successor to his classic *Modern Cosmology*, organized around "what has become the most important single problem in astronomy and cosmology"—the dark matter problem. Sciama presents lucid explanations of cosmology and the dark matter problem in general, worth reading for their clear distillations of complicated observational facts to the elements with the most essential impact on theory. It contains in particular an excellent survey of the subject of cosmic and galactic ionization, at a level of detail not found in cosmology texts.

The festschrift celebrates not only a long and productive career but a broad perspective and a generous spirit. Sciama's collaborators, students, and "grandstudents" provide interesting reviews and original essays—20 in all—on subjects ranging from galactic astronomy to quasars, from quantum measurement theory to superconducting strings. Sciama's own contribution contains a concise summary of the DDM theory. We are reminded of another remarkably compelling theory—the steady state model—that also merited considerable attention because of its eminent falsifiability. Both of these volumes are snapshots of an interesting moment in the development of theoretical cosmology; it seems unlikely that it will be possible much longer to put forward such a radically unique view of such a central subject and still be consistent with the framework of what is known.

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Advanced PCR

The Polymerase Chain Reaction. KARY B. MULLIS, FRANÇOIS FERRÉ, and RICHARD A. GIBBS, Eds. Birkhäuser, Cambridge, MA, 1994. xxii, 458 pp., illus. $79, SFr148, or DM168; paper, $45, SFr84, or DM98.

In his preface to this volume Kary Mullis confesses that books are no fun. "You can never finish your part on schedule and you feel guilty for a long time until you finally do; and then you feel like you could have done a lot better job if you hadn't been rushed." It appears that few of these contributing authors have been rushed, as they have turned out an admirable collection of chapters.