Neutrinos: An Overview and One Cosmologist's View

Neutrinos in Physics and Astrophysics

Chung W. Kim and Aihud Pevsner
Harwood, Langhorne, Pa., 1993. 429 pp.
$28.00 hc ISBN 3-7186-0567-8

Reviewed by Frank Sciulli

Our present best knowledge specifies two distinct classes of matter (leptons and quarks), each class containing three families (or flavors) of particle pairs. The known interactions of these elementary particles are well described by the standard model. Though there are many questions about all these particles, the three uncharged leptons (the neutrinos) are the most perplexing. One logical possibility is that these neutrinos have a rest mass of zero and no direct connections to each other (conservation of lepton flavor), and interact otherwise only through left-handed interactions. This is the prevailing standard model view.

There are many intellectual difficulties with this as an ultimate picture. Among them are 1) the seemingly contradictory situation that three of the twelve known types of matter should have no rest mass; 2) that the world should be constructed with inherently unbalanced left-handed interactions; and 3) that the three families of leptons, unlike quarks, have no natural connections among themselves (flavor conservation). An important tool for exploring these questions is the neutrino; the experiments that unlock its nature may well answer all questions.

Neutrinos in Physics and Astrophysics is a comprehensive description of our present understanding of the neutrino's nature as well as the limits of that understanding. The emphasis is on neutrino properties rather than knowledge that has flowed from the use of neutrinos to understand other questions. The section on neutrino–nucleon scattering, for example, is short and superficial, but other books exist that treat such subjects more completely.

The fact that neutrinos are the only known elementary particles of matter lacking electric charge makes them unique in many ways. The most important is that quantum field theory permits two physically different mechanisms to specify a finite rest mass for the neutrino. The book covers this ambiguity clearly: how neutrino mass may be of Dirac or Majorana type and the different implications for each. The inherent connection between neutrino mass and flavor violation is also well described. The apparent absence of right-handed interactions along with the obviously small masses of the known left-handed neutrinos become more natural in the exposition of the "see-saw" mechanism. Descriptions of alterna-

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Modern Cosmology and the Dark Matter Problem

D. W. Sciama
Cambridge U. P., New York, 1994. 216 pp.
$29.95 pb ISBN 0-521-43848-9

Reviewed by David N. Schramm

Physical cosmology is clearly one of the most rapidly moving areas in physical science today. Technology has reached the point where observations and experiments can probe the universe and deliver information not only from telescopes, the traditional tools of cosmology, but also from particle accelerators and experiments deep underground, in space and even at the South Pole. These observations and experiments have established the basic, hot big-bang cosmological framework and have led to the current forefront problem in physical cosmology: the origin of structures in the universe and the related dark matter question.

Dennis Sciama has been one of the leaders in this revolution in modern cosmology. His early book, *Modern Cosmology* (Cambridge, 1971), written immediately after the discovery of the microwave background radiation, was crucial to the education of readers in the new nature of cosmology. In addition to being a world-class cosmologist, Sciama is also noted for having inspired some exceptional students, including Stephen Hawking and Martin Rees.

In *Modern Cosmology and the Dark Mattter Problem*, Sciama's presentation of the basic cosmological framework and the nature of the dark matter problem is well done (although I have some quibbles with his discussion of the developments of big bang nucleosynthesis). What makes this book truly unique is that it presents in one place all the elements contributing to Sciama's own particular view that the solution to the non-baryonic dark matter problem is a neutrino with a mass of exactly 29.21 ± 0.15 eV.

While many of us in cosmology feel that neutrinos (hot dark matter) are viable candidates, either in a mix with cold dark matter or with seeds such as topological defects, nobody other than Sciama has felt that one could specify the mass of this neutrino with such precision. Most of us are content to talk about masses in the range of a few eV to a few tens of eV; Sciama, on the other hand, has developed an impressive interweaving of arguments to get a very precise mass for what he thinks the neutrino should be.

The key ingredient of his argument is that the radiative decay of such a massive neutrino provides the energy source to produce observed ionized hydrogen gas.

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tive neutrino properties are accompanied by presentations of the various implications for measurement and the status of experiments in such areas as neutrino oscillation phenomena in vacuum and matter, decay lifetimes for massive neutrinos, double beta decay, searches for the effects of relic neutrinos and many others. Comprehensive treatments are included of the solar neutrino puzzle, the limits from accelerator experiments (written prior to recent results from the Los Alamos experiments) and the tantalizing clues implicit in atmospheric neutrino data. (See page 19.)

The book is written at a level that can be followed by advanced graduate students and professional researchers with a knowledge of second-quantized field theory. It would be an excellent text for an advanced graduate course in neutrino properties as well as a very complete reference on the subject. The present intense experimental and theoretical interest in the nature of neutrinos, from neutrino oscillation experiments to studies of supernovae, should provide the book with a large audience. One would hope that the book will stimulate some imaginative researcher to delineate what is needed most: the optimal experiment pointing the way to a deeper understanding of neutrinos and their interactions.

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He argues that neutrinos that are either more or less massive than his critical number will be unable to do the job, when one takes into account such ingredients as cosmological redshift. He also notes that since there is an exact relationship between the mass of the neutrino and the fraction of the critical density that the neutrinos contribute to the universe, and also a relationship between the Hubble constant and the critical density, one can make everything fit just right: The decaying neutrino solves the ionization problem while providing the non-baryonic dark matter. Further, with the universe being at its critical density and at an age consistent with the age of the oldest stars, he also comes out with a relatively low value for the Hubble constant—as long as the neutrino has the precise mass he gives it.

This indeed is an interesting synthesis: The nice thing is that it also makes a very specific prediction about something that is susceptible to observation—the decay of this neutrino into a line in the ultraviolet. At the very end of the book, Sciama discusses the uv instrumentation being developed to look for this neutrino line radiation.

Although Sciama's neutrino scenario has been circulating in the cosmological community for several years, it was divided among many separate papers and until now was not all available in one place. Furthermore, for the nonspecialist, the book introduces and explains modern cosmology and the nature of the dark matter problems themselves rather well. It is definitely a useful addition to the cosmological literature. Incidentally, Sciama's neutrino is several times more massive than the reported Los Alamos (LNSO experiment) neutrino mixing claim. (See page 19.) Thus such a result, even if true, would not confirm Sciama's proposal.

Life in Moving Fluids

Steven Vogel
Princeton U. P., Princeton, N. J., 1994. 467 pp. $49.50 hc
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Biological organisms provide a natural laboratory for fluid dynamics because the properties of moving fluids create striking adaptive pressures and opportunities. Not only is the *fact* of fluid motion important, but so are the details. One needs to know quite a bit about such topics as pressure gradients, boundary layers, drag and momentum transport and airfoils in order to think intelligently about the ways organisms use and adapt to moving fluids.

Although *Life in Moving Fluids* is intended primarily for biologists wishing to learn about fluid motion, physicists and engineers will find in it much of interest. Written in an engaging and informal style, the book is fun to read and full of amusing examples. Anyone who has occasion to talk about fluid dynamics in teaching (even at the introductory level) would find useful examples here. This book might even stimulate more of us to do so.

Steven Vogel, a leading researcher on biological fluid mechanics, has a deep knowledge of hydrodynamics and knows how to teach the subject. Many phenomena are explained more clearly in his book than in common fluid dynamics texts: the origins and measurement of pressure variations in fluids, the significance of the Reynolds number, the physics of drag and lift, and transport mechanisms, to name a few. Readers, including those who already know some fluid mechanics, can learn much that is applicable to nonbiological situations: variables affecting the drag on cars