

ages them from accepting that the successes point away from that eventuality.

McCarthy himself did much to realize the achievements of AI. His LISP compiler was the first built on the recognition that information, not arithmetic, would be the computer's main stock in trade. He is also the parent of multi-user interactive computing. All this was achieved in the late 1950s, when cumbersome and expensive vacuum-tube machines still ruled the roost.

I can only wish this book success. It represents a genre that may appeal to the broadest of audiences, and which shows great promise for revealing science as a creative human activity.

Vectorial Astrometry

C. A. Murray

353 pp. Hilger (US dist. Heyden, Philadelphia), 1983. \$49.00

This book is the most important work on astrometry since Simon Newcomb's *A Compendium of Spherical Astronomy* (1906). For the first time since the emergence of the New Astrometry about two decades ago, one of its most active and successful practitioners has written a book that gives it an authoritative theoretical treatment. Enlightened astronomers and astrophysicists

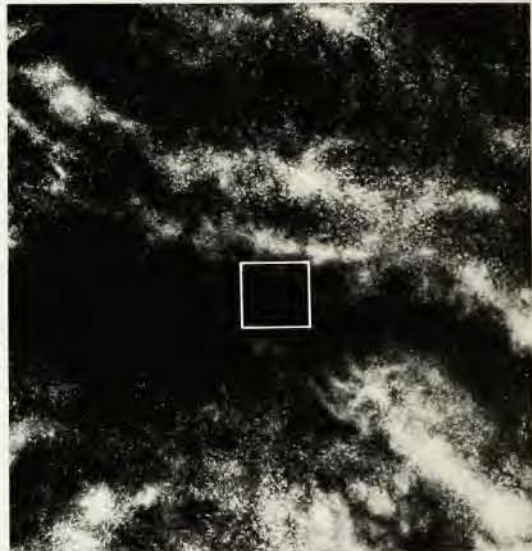
have always known that there cannot be healthy astronomy or astrophysics without healthy astrometry. Murray's book shows that this is indeed so, and in addition, that astrometry is by no means a matter for those with little talent.

Astrometry is the oldest branch of the oldest science. Astronomers and other scientists often think that astrometry is old-fashioned, that there are no astrometric problems left unsolved and that imaginative and original scholars—especially during the period in which they must establish reputations to survive as professionals—will do better to devote their energies to subjects with more front-page appeal. Unfortunately, especially in the past, this undeserved reputation drew into astrometry some relatively unimaginative individuals who spent lives of drudgery gathering large masses of useful and necessary data. Their methods, sometimes naive even when they were new, did not do the field justice. Anyone (like this reviewer) who referees a fair number of papers on astrometry submitted for publication will regularly encounter authors with little background in the subject who are forced into astrometry and, reinventing the wheel, design it as an octagon.

The subject of astrometry is the

definition and the empirical establishment of the kinematic parameters of celestial objects and the reference frames for these parameters. Since the natural mathematical tools—vectors and matrices—had not yet been invented a couple of centuries ago, the pioneer investigators (James Bradley, Friedrich Bessel) had to resort to the clumsy formalisms of spherical trigonometry when they did their work. Murray is the first author of a comprehensive treatise on astrometry who eschews not only the formulas of spherical trigonometry but also the fictitious "celestial sphere." These rejections are totally sensible in a work that deals with coordinates and their derivatives, even though the direct measurement of distances (that is, without involving directions) is at this time restricted to the objects of our solar system.

Informed investigators know that we are currently witnessing the development of new astrometric techniques, and that even the traditional methods are becoming ever more sophisticated. Most algorithms and theoretical formalisms that tradition has handed down are no longer adequate to accommodate the newly available precision and accuracy of astrometric measurements. This situation is, of course, not new.



Above (left) a depiction of our galaxy in a view 10^{21} meters across and (right) an enlargement of the area within the box, itself encompassing 10^{20} meters. The image on the right shows clouds of stars and gas, still much larger than individual stars. The pictures come from *Powers of Ten: A Book about the Relative Size of Things in the Universe and the Effect of Adding Another Zero* [Philip and Phyllis Morrison, 150 pp. Scientific American (dist. Freeman, New York), 1983. \$29.95]. The book is a transformation of the film *Powers of Ten* by the Office of Charles and Ray Eames, which itself was based on a children's book by Kees Boeke. The present book takes its readers on "a

voyage of discovery through the universe" in 42 full-page illustrations, each one magnifying the last by a factor of 10. The journey starts at a super-galactic scale of 10^{25} meters and continues, through the scale in which we are most accustomed to seeing the world, down to the insides of a proton at 10^{-16} meters. In addition, the Morrises "have organized a set of illustrated comments, lingering here and there, looking around, recalling the experience of earlier travelers, and seeking to convey the evidence that informed the carefully constructed images of the journey itself. The unity that arises so clearly out of the diverse sciences will, we hope, become perceptible and exciting . . ."

Over the past few centuries algorithms have been repeatedly modified to accommodate gains in observational precision. The result is that most algorithms commonly used in astrometry are like old houses, kept inhabitable—and quite comfortably—by many additions and remodelings that have left the original structures unchanged.

In this work, however, Murray has laid the foundations for erecting a totally new town. His approach, in contrast to that of virtually all his predecessors, is to establish a formalism for the most general situation and specialize it—always pointing clearly to where full generality is given up or where approximations are introduced—to the limitations of the accuracy imposed by contemporary measuring techniques.

The book starts with two chapters that recapitulate the space-time relations essential for astrometry from the standpoint of general relativity. In a new approach, Murray derives the traditional nonrelativistic formalism as a specialization from the generally formulated relativistic approach. He devotes the next chapters to the subject traditionally covered by the heading "spherical astronomy," a term which—appropriately—is not even mentioned in this book.

Murray covers the difficult subject of time very lucidly in the next chapter. He includes, of course, the relativistic aspects of the transformation between the proper time of the observer and coordinate time. He treats next the influence of the atmosphere on astrometry, including traditional refraction and, for the first time in a book on astrometry, those aspects of the atmospheric influence that affect radio-astrometry and interferometry.

The last three chapters cover what is traditionally considered astrometry proper. The first of these treats differential astrometry in the tangent plane, the most obvious specialization of which is photographic astrometry. The second, entitled "global astrometry," gives the theories of the transit circle, the astrolabe, the photographic zenith tube and the radio interferometer and also goes into the astrometry of non-point-shaped objects, that is, Sun, Moon and the planets. The last chapter shows how the empirical stellar reference frame (given, say, by a fundamental catalog) is tied to an inertial reference frame. An epilog points to the new age of astrometry in space, which is being opened by the US space telescope and the European HIPPARCOS.

Murray has been able to pack the principles of astrometry in the widest sense into 336 pages (not counting eight pages of references and nine of index) only by exercising some parsimony: The formulas that apply to certain

situations are developed in vector-and-tensor forms from first principles, the expansion to an explicit format is left to the reader. The book thus virtually excludes the techniques of computation. Likewise, he presents the subject as it is now. While this limitation is healthy, especially for those making their first contact with astrometry, it makes it necessary for those who practice astrometry by digging out old observations to consult older publica-

tions, such as *Spherical Astronomy* by E. Woolard and G. M. Clemence, which gives explicit formulas for all computations but obscures the essential spatial relationships in a hopeless maze of spherical triangles and almost legalistically contorted definitions.

I note with some regret that Murray, who has contributed so much to strengthen the ties between astrometry and the rest of modern science, acts principally as a reporter of the state of



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astrometry and refrains from criticizing the subjects he treats. Some of what has come down to us through many centuries could surely be improved. Is it really still appropriate to reckon angles in a hexagesimal system, with two different units (hours and degrees), no less? Has the concept of the ecliptic—such as it is—not outlived its usefulness? On the other hand, he has indeed introduced new concepts (proper direction, natural direction) where there was a need for them.

No worker in the field will be able to ignore this book without risking damage to the quality of his or her own work. It is also indispensable for the serious student. It may well show some seasoned astrometrist that the time has passed when one can engage in much modern astrometry without knowing (or at least knowing how to use) relativity. The beginner, especially the undergraduate student, will do well to study relativity and, for example, Laurence Taff's excellent *Computational Spherical Astronomy* before attempting to read Murray's volume. No library of any astronomical research institute will be complete without this important work.

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Manifolds, Tensor Analysis, and Applications

R. Abraham, J. E. Marsden, T. Ratiu
 582 pp. Addison-Wesley, Reading, Mass., 1983. \$34.95

This book is the first basic text in a series of books on global analysis, pure and applied, which is planned by Ralph Abraham, Philip J. Holmes and Jerrold E. Marsden and comprises both advanced and basic texts. The series aims at giving the keys of global analysis to a wide audience of scientists and engineers. One of the advanced texts has already appeared: *Gauge Theory and Variational Principles* by David Bleeker (1981). A second basic text, on Riemannian geometry and Lie groups, is on the drawing board.

Two of the authors of this text have previously written an advanced classic on the subject, *Foundations of Mechanics* (Abraham and Marsden, 1978), and one is currently writing a popular series *The Visual Mathematics Library* (Abraham with Christopher Shaw). The present text is a good book. It offers some of the essence of the first with the quality of presentation of the second.

What does this text cover? Basics in topology, calculus on Banach spaces, vector bundles, vector fields and dynamical systems, tensors and differential forms, integration on manifolds, applications to Hamiltonian mechanics, flu-

id mechanics, Maxwell's equations, thermodynamics and five delightful appendices. Lie groups are not mentioned. Not everyone needs Lie groups, but the stage (and the titles of the series and the books) is so well set up for them that their absence is a pity. More important, the absence limits the definitions of other concepts. For instance, the basic definition of Killing-vector fields requires the concept of group action on a manifold. In this book Killing-vectors are defined in the limited context of Riemannian geometry (that is, isometries) as the vector fields X satisfying $L_X g = 0$. A later example tells us that the flow of X consists of isometries, and isometries are defined in a later exercise. The information is there, but the picture is broken up into three pieces. Similar remarks apply to other concepts. The usual definition of vector bundles includes a statement on the group action of the structural group on the typical fiber. Without it, the key notions of structural group and transition functions, the distinction between fibers at a point and typical fibers, between trivialisable and trivialisations, are either absent or obscured.

Lie groups will, I believe, be an important part of the second basic text, and in this sense the present book is only half a book. Comments on the choice of topics, and their division between the two books will be more pertinent after the second book is published. Depending on the audience, the first book alone—or the two books combined—could serve as a basis for an excellent course in mathematical physics.

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Relativity and Its Roots

B. Hoffmann
 176 pp. Freeman, New York, 1983. \$9.95

The greatest strength of this short and very readable book, written by an award-winning Einstein biographer, lies in its thorough treatment of the "roots," the history of ideas about the relativity of motion. Though its tone suits a lay audience, even a working physicist may find some surprises in this narrative.

Relativity, Banesh Hoffmann reminds us, is as old as Western philosophy itself. Most of us know of Aristarchus of Samos, but he begins from Philolaus, whose moving-Earth (but not heliocentric!) cosmology came two centuries earlier. He touches briefly on the contributions of Nicolaus Copernicus, Johannes Kepler, Galileo Galilei and René Descartes on the way to the most "interesting" case, that of Isaac Newton. Here he dwells on the curious fact that the very thinker who en-