about the Sun's location in the Galaxy.

The second astronomical essay is on Edwin Hubble's extragalactic research. Even a discovery as monumental as the expanding universe could not rightly be called Copernican, although it might fit Neyman's definition of quasi-Copernican. However, the next two astronomical essays—on explosive events and modern riddles in cosmology—are, if anything, proto-Copernican. The entire volume consists of such an epistemological and philosophical jumble. But even though the book's elucidation of post-Copernican revolutions may not be impeccable, it provides a fine précis on highly significant and novel developments in many sectors of science.

For instance, David Hubel claims that neurobiology has never had a Copernican revolution; and if it ever does, the effect will doubtless be gradual, spreading over decades. And he adds that the one great remaining question of science is "whether or not [the mind] is something more than a machine of great complexity." Seaborg, however, asserts that the "evolution of the whole field of the transuranium elements ... constitutes a real Copernican revolution." Although his account is engrossing, his evaluations of the field's long-term philosophical importance surely is overstated.

Several authors lamely attempt to weave their disciplines into the Copernican mosaic. In his pedagogically stunning essay on relativity theory, Rainer K. Sachs attempts to liken special relativity to Copernicus's heliocentricism and the Michelson and Morley experiment to Ptolemy's epicycles. Victor F. Weisskopf, in contrast, in an elegant essay on quantum theory, simply ignores the Copernican theme: he gives the facts, allowing the reader to make his own metaphors.

Besides philosophy, memorable miscellanea are sprinkled throughout the volume. We learn that the world's first computer programmer—Lord Byron's daughter, the Countess of Lovelace—lost her fortune betting on an "infallible" mathematical system for horse races. And Student's t-table came from W. S. Gosset, a chemist in the Guinness Brewery, who wrote under the pen name of "Student."

Many contributors use seductive pedagogical techniques and provide subtle insights. Stever, after rightly noting the supreme significance of the Wright brothers' first flight, ranks it as non-Copernican; instead, he calls Cayley, of a century earlier, the "true inventor of the airplane." Robert L. Carman, writing on lasers, astutely shows that breakthroughs can be evolutionary rather than revolutionary. But he fails to note the evolutionary nature even of the Copernican revolution: In a sense it was started by Aristarchus, aided by medieval anti-Aristotelians, accelerated by Copernicus, facilitated by Tycho and Kepler, proved by Galileo, and established by Newton.

Of all the attempts here to find latter-day Copericanism, possibly the most convincing is by Robert L. Sinsheimer, who argues that the overthrow of vitalism—the belief that living matter differs from non-living by the presence of a mysterious power in each fundamental part—was in fact Copernican. He presents the case well, noting that the breakthrough came gradually, even painfully; but once reached, it had profound influence in medicine, psychology, and other fields. But even this signal impact pales beside the monumental revolution attributed to the man from Torun.

One of the most exciting aspects of science is its incompleteness. Would it not, therefore, be the scientist's nirvana to read now the NAS commemorative volume to be published in the year 2473. Of what new revolutions would we read, and would Copernicus still be without peer?

* * *

Richard Berendzen is dean of arts and sciences at the American University, Washington, D.C. He does research on the history and sociology of science and is coauthor of Man Discovers the Galaxies.

Ion Beams With Application to Ion Implantation

R. G. Wilson, G. R. Brewer
500 pp. Wiley, New York, 1973. $19.95

If you are planning to install a low energy (10–500 keV) heavy-ion accelerator and are confused by the conflicting claims made for different ion sources and analyzing systems, this book should prove invaluable. The authors have distilled their many years of experience in working with such machines into a helpful guide to the novice. If you are presently working with such machines, the information in this book should allow you to optimize the machine's performance as well as provide many helpful operating hints.

The authors, Robert G. Wilson and George R. Brewer, start with a lengthy description of the mechanisms of producing ions and discuss a whole array of ion sources (such as surface-ionization sources, FR sources, Plasmatrons, oscillating-electron ion sources and others). Their discussions are not limited to a brief description of the sources but include the advantages and shortcomings as well as typical operating parameters and results for each type of source. Many of the graphs for ion-source parameters stem from their own unpublished work. The authors are able to remove the "sorcery" part of "ion sorcery." The discussion of ion-beam extraction and transport system utilizes matrix representation of ion optics. This is a very convenient and powerful method, especially when digital calculating machines are available. Basic ion or electron optics are not treated thoroughly by the authors but an ample bibliography more than makes up for this omission. For beam-analyzing systems the authors recommend a crossed electric and magnetic field velocity selector (Wien filter) and give a good theoretical treatment of this analyzing system. The theoretical results are interwoven with results from actual working systems, and many practical limits are given. The last section of the book, on system-design considerations of ion implantation systems, should prove very helpful for anyone who is presently in the planning stage for such a facility. All chapters have an extensive and adequate bibliography and additional information (vapor pressure of materials, toxicity of gases) that is very helpful in operating ion sources and small accelerators.

When the authors review the basic physics required for ion implantation (including stopping power, range theory, channeling and sputtering) the treatment is very elementary, even misleading in certain instances, and does not approach in rigor or sophistication the description they give of ion sources or beam-transport systems. This is a serious shortcoming of the book, because an intelligent discussion of this subject would be extremely valuable to workers in this field.

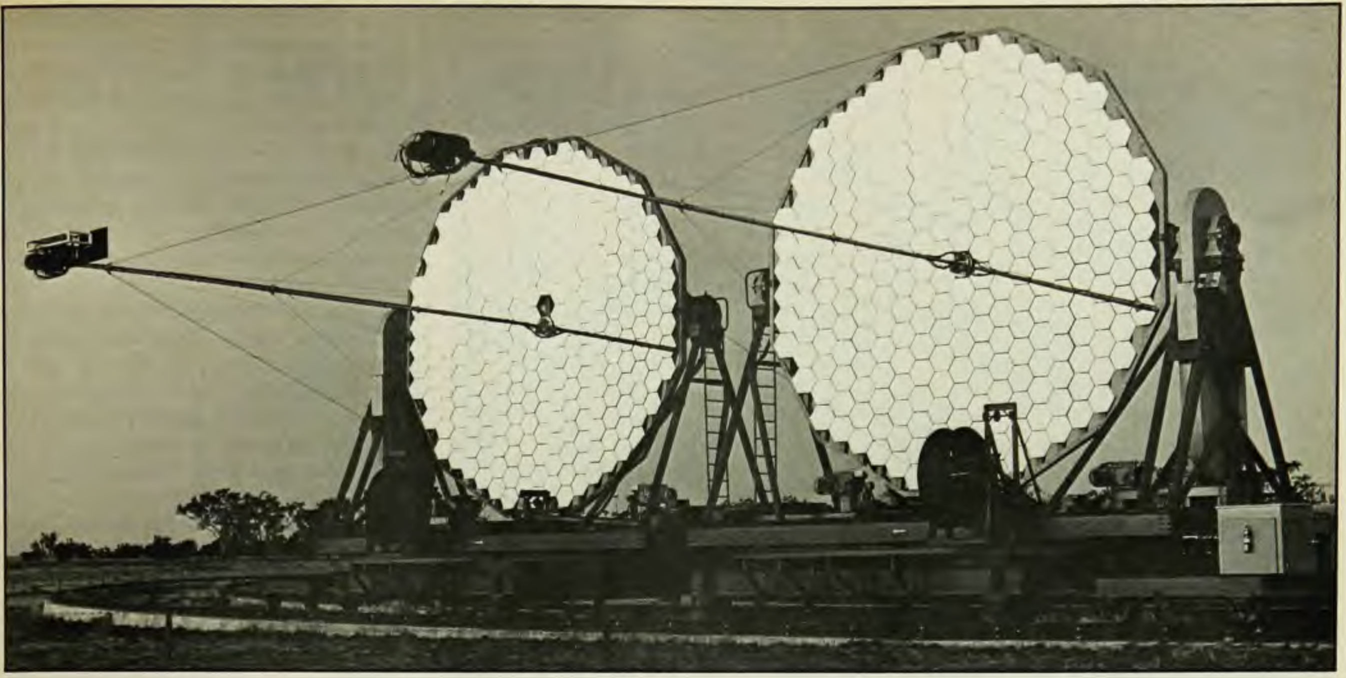
ROMAN LAUBERT
New York University
New York, New York

The Intensity Interferometer, Its Application to Astronomy

R. Hanbury Brown
184 pp. Halsted, New York, 1974. $18.75

As dusk falls on the Australian plains, two seven-meter-tall mosaic mirrors move into position on the circumference of a 188-meter-diameter circle and follow a single star across the southern sky. A photomultiplier tube at the focus of each samples an eight-nanometer slice of the star's spectrum and sends a 100-MHz bandwidth signal via a tenth of a kilometer of coaxial cable to a correlator that measures the time average of the product of the signals from the two tubes. Each night, as the mir-

PHOTO BY R. HANBURY BROWN



rors are moved farther and farther apart, the time average of the product of the two intensities decreases, tracing out the second-order spatial correlation function of the light from the star arriving at the Earth. Since the correlation function is the square of the Fourier transform of the star's angular brightness distribution, the intensity interferometer measures stellar angular diameters. It embodies the present limit of Man's ability to measure astronomical angles, an ability that stretches from the 0.2-milliradian capability of the naked eye to the ultimate 0.5-nanoradian uncertainty of this unique instrument.

Robert Hanbury Brown helped to establish the field now known as "quantum optics" by his theoretical analysis and measurements on the correlation between the output of the two square-law detectors, both sampling the same beam of radiation. The early opposition was considerable; two separate experimental groups "proved" that it could not be done. By 1957 the correlation had been seen both between the multiplied detector currents and between individual photon events from two detectors, and the controversy switched to whether second-order correlation required a quantum mechanical description or was a classical consequence of the chaotic radiation field being a Gaussian stochastic process. The resolution of the problem helped to emphasize the power and convenience of the coherent states of the quantized electromagnetic field.

Hanbury Brown's book is a superb description of the conception, theory, design, construction, testing and use of the stellar intensity interferometer at Narrabri. Astronomers will find here a list of the angular diameters of 32 stars that have been measured between 1965 and 1972, along with the actual radii, temperature, and emitted flux of a smaller number of stars for which auxiliary data are available. The instrument discovered several new double stars for which it can provide the individual angular diameters, brightness ratios, and angular separations. Analysis of the data from Spica is the most complete, filling a full page with axis angles, orbit shape, period, sense of rotation, and, in combination with spectroscopic data, the distance, absolute magnitude, mass, radius, surface gravity and temperature of each constituent of this binary system whose maximum separation is less than 3×10^{-3} seconds of arc. The angular-diameter data are supported by a complete description of the parameters of the instrument, data-taking conditions, corrections and uncertainties that sets a high standard for the reporting of experimental results.

Here too are the experimental problems, from drifting electronic correlators to yellow-throated miner birds pecking at the mirror surfaces, together with the experimental philosophy and skill that led to their solution. (The bird problem was solved in an ecologically efficient way.)

Those interested in quantum optics, partial coherence, and signal processing will find a clear classical description of intensity interferometry, an application of second-order spatial correlation in which optical path lengths (including the effects of atmospheric scintillation) must be held constant only within millimeters rather than within the 100 nanometers or so required of conventional interferometers. Several chapters are devoted to the theory of partially coherent light and to its application to first- and second-order interferometry.

This book is the record of a body of work that has contributed to our knowledge of the electromagnetic field and of the diameter of stars. It will be a long-lasting addition to the literature of physics and astronomy.

DONALD SCARL
Polytechnic Institute of New York
Farmingdale

Crystal Chemistry of Non-Metallic Materials Vol. 4: The Major Ternary Structural Families

O. Muller, R. Roy
487 pp. Springer-Verlag, New York, 1974. $31.20

This book is volume four of a series edited by R. Roy and is concerned with the crystal chemistry of nonmetallic materials. Unfortunately, volume 1 (R. Roy and R. E. Newnham, *Principles of Crystal Chemistry*), volume 2 (R. E. Newnham, *Properties of Solids in Relation to Structure*), and volume 3 (O. Muller and R. Roy, *The Major Binary Structural Families*) are still in preparation, so that I am unable to discuss this volume in the context of the series. The authors hope that this series will serve as textbooks and reference volumes for graduate students mainly in materials science, ceramics and geochemistry and for practicing materials researchers.

The approach taken by the authors is to discuss the structures, interrelation-