roads, blood banks, and agriculture, most of the world's big problems are still untouched with, on the other, a hope that operations research, or methods like it, may someday help with the bigger problems.

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Stellar Atmospheres

Abundance Effects in Classification. Proceedings of a symposium, Lausanne-Dorigny, Switzerland, July 1975. B. HAUCK and P. C. KEENAN, Eds. Published for the International Astronomical Union by Reidel, Boston, 1976. xxviii, 264 pp., illus. Cloth. $31.50; paper, $22.50. IAU Symposium No. 72.

Physics of Ap-Stars. Proceedings of a colloquium, Vienna, Sept. 1975. WERNER W. WEISS, HELMUT JENKNER, and H. JOHN WOOD, Eds. Universitätssternwarte Wien mit Figl-Observatorium für Astrophysik, Vienna, 1976. xvi, 754 pp., illus. Paper, $26. IAU Colloquium No. 32.

Be and Shell Stars. Papers from a symposium, Bass River, Mass., Sept. 1975. ARNE SLETTEBAK, Ed. Published for the International Astronomical Union by Reidel, Boston, 1976. xvi, 466 pp., illus. Cloth, $56.50; paper. $43. IAU Symposium No. 70.

Sometimes it happens in science that too much information can obscure fundamental relationships and processes. One may wonder if Kepler would have decided that the orbits of the planets were ellipses if the observations of Mars by Tycho Brahe had been accurate to 5 arc seconds instead of 8 arc minutes. The latter accuracy was sufficient to determine the elliptical nature of the orbit, the former would have shown the perturbations of the other planets. In a similar way, stellar classification using low-dispersion spectra (100 Å/mm) is sufficient to divide about 80 percent of the bright stars into a unique, two-dimensional array with axes that correspond to surface temperature and to surface pressure or gravity. In addition to these two parameters, however, the atmosphere of a star is characterized by its chemical composition. Between 1930 and 1940 some groups of stars were found in which the abundance of certain metals relative to hydrogen is anomalous, and this knowledge led to the realization that surface composition varies from star to star and that differences in abundance affect classification indices. The effects of such differences on classification were the subject of IAU Symposium No. 72, *Abundance Effects in Classification*, which was dedicated to W. W. Morgan, whose careful work dominates the field of spectral classification. It is possible, at classification dispersion, to distinguish between stars with "normal" and those with "peculiar" chemical composition. Previous discussions of classification systems have demonstrated the increasing importance of abundance effects. Symposium No. 72 provides those interested in stellar abundances with a survey of the subject as it stands now and with an indication of the directions that future lines of research are likely to take. In addition to the submitted papers, the invited reviews by both theoretical and observational experts comprehensively cover our present understanding of the subject. Particularly noteworthy is a catalog of atmospheric parameters and Fe/H determinations that will be useful not only to those astronomers interested in the problems associated with abundance but also to those who from time to time need a catalog of the chemical compositions of stellar atmospheres. The proceedings end with a short discussion by Morgan of spectral classification, including what might best be described as some advice to a young person for future work in the field.

The other two volumes under review also deal with stellar atmospheres. IAU Colloquium No. 32, *Physics of Ap-Stars*, concerns A and B peculiar (Ap, Bp) stars, those stars that have surface temperatures ranging from about 7000°K to 20,000°K and that exhibit abnormally high atmospheric abundances of certain elements, such as the rare earths. Many of these stars have very strong magnetic fields organized on a global scale. Their field strengths range from several hundred gauss to several tens of thousands of gauss. At classification dispersion, these stars have been divided into various categories, such as silicon or mercury-manganese stars, but at higher dispersion the abundance peculiarities increase and their division into a few simple classes is not possible. While ordinary stars in this temperature range typically exhibit rapid rotation, all the Ap and Bp stars are slow rotators; in fact, one such star is thought to take over 70 years to complete a single rotation. The abundance anomalies of these stars are concentrated near their magnetic poles, which are not usually aligned with their rotation axes and which produce spectrum changes as the star rotates.

L. Mestel reviews the magnetic field models that have been proposed to explain the abundance anomalies of Ap stars. The principal issue such models address is whether the field is the remnant of a primordial field "frozen" into the stellar plasma or is continuously being created by dynamo activity. F. A. Catalano reviews the origins of the abundance anomalies: Are they produced by diffusional separation, by nuclear activity on the surface of the star, by selective trapping of interstellar gas by the star's magnetic field, or by one of several other processes?

Among the numerous observational papers are a review of the ultraviolet properties of Ap stars by D. S. Leckrone, a review of the atmospheric parameters of Ap stars by M. Hack, a description of an investigation of element identifications in peculiar stars by C. R. Cowley, a review of the mercury-manganese stars by S. C. Wolff and R. J. Wolff, and a delightful paper discussing the metallic line stars by D. J. Stickland. The colloquium volume concludes with open discussions of several of the controversial theories and major problems in the study of these stars: those associated with the origin of their magnetic fields and their peculiar chemical composition, with the mercury-manganese and related stars, and with line blanketing and the transfer of radiation through the stellar atmosphere. It is clear that although we have a large amount of observational information concerning these stars, we still have no self-consistent theoretical model that explains all the observed data.

I would like to compliment the editors on the inexpensive way they have chosen to publish the proceedings; the paperback binding and photo-offset printing enable the book to be distributed without excessive expense.

IAU Symposium No. 70, *Be and Shell Stars*, treats another class of hot, peculiar stars. The spectra of these stars are characterized by emission lines and broad absorption features. Otto Struve in 1931 connected the broad absorption lines of these stars with their rapid rotation and concluded that it was likely that the emission lines were produced by a disk thrown off from the equator of the rapidly rotating, hot star.

As with the Ap stars, there is at present no consistent theory explaining all the properties of the Be stars. There are theoretical and observational difficulties with Struve's model. Competing models, such as one offered by S. Kříž and P. Harmanec that postulates that many or all Be stars are mass exchange binaries, require additional theoretical and observational justification before they can be accepted.

Symposium No. 70 has the flavor of a meeting of a working group. The review

papers are informative and well presented. Those that struck me as particularly valuable include ones by J. B. Hutchings on spectra and photometry, by A. Slettebak on rotational observation of Be stars, and by D. G. Hummer on line formation in expanding atmospheres. As W. P. Bidelman points out in his concluding remarks, emission lines in early-type stars are produced by a number of different mechanisms, and, despite the stars' Be classification, no one model is likely to be successful in explaining their properties. The symposium clearly sets out the uncertainties in our understanding of the Be phenomena. As in the case of the Ap stars, the observational data overwhelm our ability to deal with them theoretically. This results not from a lack of effort on the theoretical side but rather from the great mathematical difficulties of constructing models that are sufficiently realistic to explain the observations.

Struve's 1942 comment about Ap stars may apply to Be stars as well: We are convinced that at least "the phenomena are not supernatural."

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A Minority View in Geophysics

The Expanding Earth. S. WARREN CAREY. Elsevier, New York, 1976. x, 488 pp., illus. $34.50. Developments in Geotectonics 10.

The idea of a significant expansion of the earth is anathema to most earth scientists, but not to S. Warren Carey, who has advocated it for a long time. The last presentation of his ideas to a major audience occurred at a continental drift symposium nearly 20 years ago, at which time the ideas of continental drift, seafloor spreading, and plate tectonics were not accepted as they are today. Many of the arguments he presented for the theory of the expanding earth are the same as those that are now acceptable for the theories of plate tectonics and continental drift. Since many aspects of plate tectonics are minor premises of the expanding earth syllogism, Carey thinks we have not looked hard enough at the entire story he has to tell.

The idea of earth expansion is not original with Carey. It was first proposed by Lindemann 50 years ago, and about 40 years ago P. A. M. Dirac concluded that the gravitational constant G varied inversely with the age of the universe. More recently, Egyed, Owen, Dicke, and others have espoused earth expansion under one guise or another.

Better than most continental drifters, Carey deals with the geometry of continents, how they may have drifted or been deformed, and the tectonic evidence of the phenomenon. He considers deep earth structure and possible relations among solar, planetary, and terrestrial phenomena. He does this with great vigor and in considerable detail, referencing many little-known Soviet works, as well as the most recent publications in the Western literature. He starts with the assumption that we have not yet discovered all the cause-and-effect relationships and an alternative look at the data is worthwhile.

He does not, however, philosophize deeply on what makes a cause-and-effect relationship acceptable, that is, on how we establish a theory in the observational earth sciences, where laboratory experiments and repeatability tests are impossible.

The book is not as tightly organized as some with so unitary a subject. It includes expostulations on related subjects and critiques of other papers to illustrate alternative interpretations. There are four main sections, whose titles only vaguely reflect their contents: Introductory Review, Some Principles, Regional, and Retrospect. The format appears to be author-produced, with typed pages and nearly all figures being Carey's own drawings and sketches.

Possibly the most easily accepted part of Carey's work is his hypothesis about how continents have moved and been shaped in the last 200 million years. He recognizes only a few types of continental deformations or interactions. These he gives special Greek names (such as rhombochasm and oroclinotath), which are difficult to pronounce or remember. Plate tectonicists have had little quarrel about the occurrence of these continental movements, because they are geometrical in nature and largely consistent with plate tectonic theory.

Possibly the least easily accepted part of Carey's work is his explanation of deep-sea trenches. He finds it easy to believe that the mid-ocean ridges are the foci of seafloor spreading (by earth expansion, rather than by conveyer-belt motion), but believes there is no subduction down trenches, only upward motion behind them. The difference between the passive Atlantic continental margins with no trench or associated volcanic earthquake belt and the active Pacific margins with prominent trench and volcanic earthquake belt is, he thinks, primarily a matter of oceanic sedimentation rate. Many would agree that the structure of many passive margins is consistent with their being filled trenches, but we know that there are few filled trenches adjacent to the ring of fire around the Pacific. He points out that plate tectonicists are open to criticism when they have the seafloor moving under Japan in the western Pacific while the spreading center has been swallowed under the North American continent. He points out that if all adjacent continents (and their mid-ocean ridges) are moving away from Africa we have a problem of a missing subduction zone around Antarctica. These and other points he makes cause the plate tectonicist to feel uncomfortable.

One of the main observational facts that supports the idea of seafloor spreading in preference to the expanding earth theory is the sequence of linear magnetic anomalies marking the precise increase of age of the seafloor away from the mid-ocean ridges. Carey recognizes the existence of these and says they are not inconsistent with an expanding earth, but he does not prove the case.

How much did the earth expand? The answer to that depends upon which author you talk to, which part of the earth you are considering, and what age you are referring to. Some say that the radius in the late Paleozoic was only 0.7 what it is today, others that it increased with time or pulsated. Carey is a great proponent of localized uplift, calling areas of uplift "geotumours."

What caused the earth to expand? The author says simply "I do not know." Is the earth undergoing a phase change at constant mass? Is the secular decrease in the gravitational constant a fundamental law of nature? Perhaps these questions need be considered only after there is agreement on observational evidence.

Many scientists do not know of Carey's work because his publications are few. Of those who do, few accept all his ideas, although they universally find him a refreshing thinker and a true scholar. His fertile mind has covered so much megageophysics that it will come as no surprise if, in the future, many of his ideas are found to strike very close to the mark. Carey, who is retiring this year from the University of Tasmania, has made a substantial contribution to earth science during his career and will be especially long remembered for this stimulating and controversial book.

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