Stellar Atmospheres should be on the more modern techniques. Yet, one of the most welcome features of this book is that *both* 'classical' and 'modern' methods are discussed. Chapter 6, on construction of models and prediction of continuous spectra, assuming LTE, is followed by the description of two paths of approach when some of the occupation numbers are allowed to depart from their equilibrium values. Similarly Chapter 11, on line formation in LTE, is followed by two chapters on the non-LTE methods. The first of these considers conceptual aspects, using for illustration a simple two-level atom. This chapter should be strongly recommended to anyone seeking a sound understanding of line formation processes. Chapter 13 introduces the techniques used in more realistic and complicated cases. Examples of line transfer are given for lines of only hydrogen, calcium, and sodium, but this field is progressing rapidly and 'we should not be too surprised if many of our LTE interpretations are changed when a more complete theory is employed'.

Most of the applications of theory are given for stars hotter than the Sun. The physics of hot atmospheres is now rather well understood and the limitations in accuracy are largely computational. In the case of cooler atmospheres not only is the mathematical complexity aggravated by the greater number of absorption lines which must be taken into account (and which certainly influence the atmospheric structure), but there is a gap in the physics as well. Energy may be transported by radiation *and* by convection, and a completely reliable theory of convective energy transport is not yet in sight. Criteria by which the onset of convection can be recognized and a review of the approximate convective theory now in use are given, and the importance of the special information provided by studies of the Sun is stressed. In view of the difficulties in applying the most modern methods to cool stars, and of the importance of studying stars of widely differing ages (hot, unevolved stars are, on a galactic scale, quite young), the 'classical' methods may be expected to continue to be of use.

The chances of losing readers in mathematical thickets are minimized by Professor Mihalas' direct, lucid style. Derivations and proofs are preceded by clear statements of what's about to happen, and why. Still, this is a no-nonsense textbook meant to provide 'a minimum background for the student who wishes to understand the literature and to do research in the field'. It definitely will *not* appeal to the non-astronomer seeking a leisurely description of what stars are like (although those with strong analytical leanings and ample free time might find in the stellar atmospheres problems an interesting example of applied mathematics). Specialization being what it is, it is probably safe to say that this book will not be read by the majority of astronomers. Nevertheless, those for whom it is intended will welcome it gratefully, and its stated purpose should be completely fulfilled. *Stellar Atmospheres* is one of the most important books on astronomy to be written in recent years.

Unfortunately misprints (and, oddly, omissions of single letters and words) abound. I counted seven in Chapter 1 alone, one in the Preface, and even one in the Table of Contents.

DAVID BRANCH

Introduction to meteorological optics

By R. A. R. TRICKER. *London: Mills & Boon; New York: Elsevier, 1970. pp. 284. £4.20.*

It is often helpful, when assessing a scientific work, to think of it as being like a poem, and examine how its *form* matches its *content*. In this context form refers not to the mere arrangement of chapters, but to the fundamental scientific theories that are invoked to explain a group of phenomena taken from nature or technology, while the phenomena themselves constitute the content. There exist some books which in this sense are all form and no content: it is possible to find texts on mechanics, for instance, which would not lead one to suspect that outside their pages there exists a world whose phenomena provoked the development of the theory in the first place. Such books fulfil a perfectly legitimate function in schooling the research worker in the tools of his trade, and in any case the purely formal development of theories is an indispensible part of science. It is peculiarly difficult to get this across to the layman, who wants to know what science can explain, and what it can help us do; for him the content is paramount. Between these extremes lies the student, whose education requires an appreciation of the subtle and complex relationship between the theories on the one hand, and the world on the other.

Student texts are, in the main, based around a theory—a form—and the content appears as 'illustrative examples'. We may call this approach *analytic*; it has the advantage of being relatively easy to use for teaching, because it is systematic. Much rarer is the alternative *synthetic* approach, centred on a group of phenomena (content) such theories being introduced as are necessary to explain them. (As an illustration, a course or text on the interiors of stars would involve the theories of nuclear reactions, radiation and thermodynamics.) It is a pity that more teaching is not synthetic in this sense, since most students' interest was initially kindled by the phenomena, and most research workers are concerned basically with explaining some definite phenomena or process, rather than exploring the structure of a theory.

In terms of our system of categories, it is easy to place this superb new book on meteorological optics. The approach is entirely *synthetic*, with the unusual feature that all the phenomena can be dealt with within the framework of a single theory—classical optics. By easy stages, in the course of explaining mirages, haloes, rainbows, coronae, glories, etc., Mr Tricker gives simple and clear expositions of the theories of refraction (in continuously-varying media and at interfaces), interference, polarization, diffraction and the partial-wave theory of scattering. Because of the peculiarly close marriage of form and content, this book is eminently suitable as an auxiliary text for undergraduate students of waves or optics; it is particularly to be recommended for teachers of physics at all levels.

There is another, quite separate, reason for exposing our students to books such as this. As is well known, the young these days are disenchanted with science, because of its connections with pollution, the arms race, etc.; they are turning away, towards politics, or mysticism. Because of this, we are faced with the problem of presenting our subject (and ourselves) in new and more appealing ways, free from these odious associations. Meteorological optics, involving some of the most beautiful of all the natural phenomena, points to a possible such approach: could we not emphasize anew the old notion of the scientist as creator of the strange poetry of nature, rather than as the whore of the military-industrial complex? Mr Tricker, of course, has probably not written his book in this spirit: without in any way detracting from his subject, or from the elegance of his arguments, he writes in a deadpan style, as befits a former H.M. Inspector of Schools. There is none of the reverential sweetness of tone that characterizes the late Professor Minnaert's semipopular book *Light and Colour in the Open Air*, which deals with the same subject.

Quite apart from its pedagogic value, the appearance of the first text for half a century devoted entirely to meteorological optics is an event of considerable academic importance. The review of phenomena is comprehensive, and only one omission springs to mind: there is no mention of the green flash which often appears at sunrise or sunset as a consequence of atmospheric dispersion and scattering, and which has been extensively investigated at the Vatican Observatory.

The author has brought a refreshing independence of mind to bear on his subject; this is particularly evident in the chapter on the heiligenschein, where he explodes an old error due to Pernter, which has found its way into the textbooks, to the effect that the halo around the reflection of one's head on dewy grass is due to strong back reflection from the front faces of the drops. By means of elegant experiments illustrated with well chosen photographs, Mr Tricker convinces us that the true explanation is probably that proposed by Lommel a century ago, whereby it is light focussed by the droplets onto blades of grass, and reflected back again, which is responsible for the selective back reflection.

The book divides roughly into two parts, the first dealing with those effects that can be explained by geometrical optics, and the second with diffraction phenomena. The first half culminates in a chapter on ice particle haloes, which for this reviewer is the most impressive part of the whole work. This is a virtuoso exercise in geometrical optics combined with spherical geometry, in which a great variety of arcs, haloes and cusps are explained in terms of the different ways light can be transmitted and reflected by hexagonal ice crystals in the form of plates and needles. Whether a given such phenomenon is rare or commonplace depends on the degree of orderliness of the arrangement of crystals necessary for its observation, and this is analysed, in a brief but elegant discussion, based on fluid mechanics, of the different modes of descent of particles of different shapes and sizes (this is virtually the only excursion in the whole book away from optics into another theoretical domain).

The treatment of the rainbow wisely separates those aspects which can be understood solely on the basis of geometrical optics from those requiring rather sophisticated diffraction theory. By using the simplest and most direct arguments, which are a joy to follow, we are led step by step up a conceptual staircase which culminates in the derivation of Airy's famous integral for the intensity of light near a rainbow edge, which is required for an explanation of the supernumerary bows.

There is only one place where Mr Tricker falls into serious error, and that is in his theory of the glory. This dramatic phenomenon resembles the heiligenschein in being due to strongly selective back reflection from water droplets, but it occurs not from dew but from clouds, and it is a subtle diffraction effect. It has long been recognized that the observations could be explained in terms of the diffraction of rays returned in the backward direction after one internal reflection, but the difficulty has been that in the case of water droplets (in contrast to glass spheres) there are no such rays reflected to within 14° of the backward direction. Rejecting as implausible a suggestion of van der Hulst that the required backward-travelling rays could be produced by surface waves skipping around the sphere, the author ingeniously postulates that the explanation be sought in the backwards diffraction of the intense light emerging at the rainbow angle. But this effect would not provide anything like the intensity observed in the glory, and in fact van der Hulst's explanation is correct, as has been shown by the recent intricate theoretical investigations of Nussenzweig, who finds that, mathematically, the surface waves originate in the 'Regge poles' which have been invoked in recent years by particle theorists to explain high-energy scattering experiments. It would be hard to think of a more striking example of the way in which an abstruse theoretical concept introduced in one field of physics can be translated into quite a different language, to deal with quite different phenomena; it is a pity that there was no place for it in this work.

The book is well produced, and not too costly in terms of the inflated price levels of today for scientific texts. The level of presentation is too high for all but the most determined laymen; such readers would be better off with the book by Minnaert already mentioned. For scientists interested in the subject, however, as well as students and teachers of physics, and those intending to do research in the field, this unique introductory text could not be bettered.

MICHAEL BERRY

Physics

Fourier methods in crystallography

By G. N. RAMACHANDRAN and R. SRINIVASAN. *pp. xiii+259. New York and London: Wiley–Interscience. 1970. £7.50.*

The scattering of X-rays by matter is mediated by electrons. When the matter is in the form of a crystal, which is seen by the X-rays as a three-dimensional periodic array of electron density, the scattering takes the form of discrete beams to each of which may be assigned a triplet of integers (h, k, l) corresponding to orders of diffraction in three directions. The intensities, I_{hkl}, of these diffracted beams (reflexions) and the directions in which they occur constitute the experimental data with which the structural crystallographer must solve his problem.

From the symmetry of the values of I_{hkl}, including the systematic absence of some classes of reflexions, from the statistics of the distribution of the values of the Is and, sometimes, from physical tests one can often unambiguously determine the space group—that collection of symmetry elements which defines all the symmetry relationships in the crystal.

The individual magnitudes of the Is contain information about the positions of atoms within the unit cell of the crystal. The experimental intensities can be modified by factors to allow for the state of polarization of the incident X-ray beam and also the geometrical arrangement under which the diffraction data are collected and may then be scaled so that the square root of the resultant quantity gives the structure amplitude, $|F_{hkl}|$. This is the magnitude of the structure factor, F_{hkl}, which is, in general, a complex quantity with an associated phase ϕ_{hkl} so that $F_{hkl} = |F_{hkl}|\exp(i\,\phi_{hkl})$.

A knowledge of the Fs, both in magnitude and phase, corresponds to a knowledge of the complete crystal structure. The electron density at any point in the unit cell with fractional coordinates (x,y,z) is given by

$$\rho(x,y,z) = \frac{1}{V}\sum_{h=-\infty}^{\infty}\ \sum_{k=-\infty}^{\infty}\ \sum_{l=-\infty}^{\infty} |F_{hkl}| \times$$

$$\cos\{2\pi(hx+ky+lz)-\phi_{hkl}\}.$$

Experiment gives us the values of $|F|$ but not the phases and it is this which constitutes the phase problem in crystallography.

This book is devoted to a description of methods of overcoming the phase problem which are based on the use of properties of Fourier syntheses. The basic theory of the scattering of X-rays by individual atoms and by crystals is given in the first chapter and the physical