Space Travel Comes down to Earth

Astronomy, the so-called impractical science, has become of intense immediate concern to John Q. Public.

John B. Irwin

Space travel has changed dramatically in the past few years from a subject for idle speculation into a sharp pain in the taxpayer's pocketbook. The first sputnik in 1957—and those that followed—caused widespread reverberations in such different fields as defense, diplomacy, education, engineering, journalism, politics, science in general, and astronomy in particular. As a result, many engineers and nonscientists find themselves urgently in need of a quick education in the astronomical facts of life. There is also a growing demand for trained astronomers, ranging from experts in celestial mechanics to theoretical astrophysicists, which our graduate schools cannot even begin to meet. Ten years ago it was difficult for an astronomer to find a publisher; now, it is difficult for an astronomer to hide out from the publishers. The seven books reviewed here are all intended in one way or another to inform the general public about astronomy from a variety of points of view.

Three Popular Books

Space in Your Future, by Leo Schneider (Harcourt, Brace and World, New York, 1961. 260 pp. $3.75), is written for school children by a well-known writer who is also a science teacher. It is attractively and profusely illustrated by photographs and especially by Gustav Schrotter's line drawings. Useful lists of solar and lunar eclipses and of planetaria and astronomical societies in the United States are given in the appendixes. A considerable number of simple but thought-provoking experiments that can be performed by almost anyone are scattered throughout the book. Visits made to hypothetical astronomers at the Yerkes Observatory and the Dominion Astrophysical Observatory help to give an intimate look at the work of the professional astronomer. However, there is a debit side: the scientific reasons for space observatories, given on page 227, could be usefully amplified. The book is marred by some errors and deserves better scientific editing. For example, on page 173 we find a diagram of a slit spectograph without collimator or camera lenses; on page 177 the galactic rotation diagram is poor both as to the nature of that rotation and the relative position of the sun with respect to the spiral arms; on page 186 cosmic rays are incorrectly made a part of the electro-magnetic spectrum.

H. C. King, the author of **Astronomy** (Watts, New York, 1960. 256 pp. $4.95), is chief astronomer of the London Planetarium and has also written an excellent professional book on the history of the telescope. *Astronomy* is written for the type of audience that is attracted to planetaria; the quality of the paper is poor, however, and the quality of the illustrations, which are often garishly colored, ranges from extremely good to very poor. About one-third of the book deals with the stars and galaxies. The book should appeal to the youthful mind and may well steer many a youngster into an astronomical career.

James Stokley's **Atoms to Galaxies** (Ronald, New York, 1961. 361 pp. $6) is a very well-written popular book by an accomplished science writer who was once a planetarium director. Of particular interest in this book is a 30-page chapter on travel in space. The flavor of the writing is indicated by some of the subchapter headings: Denuded atoms, Stations in space, Nine tons to the cup, Needle-shaped dust, Radio to the rescue, The cepheids that weren't there, Out of the primeval atom, Looking backwards into time, Planets from roller bearings, and The sun's long future.

Astronomy without Mathematics

Planets, Stars, and Galaxies, by Stuart J. Inglis (Wiley, New York, 1961. 474 pp. $6.50), is an up-to-date college text written especially for students of the liberal arts and for other readers who have no mathematical or scientific background. It is very similar to many other well-organized and attractive college textbooks on elementary astronomy except that the amount of mathematics in it has been made vanishingly small. There are especially interesting chapters on the evolution of the stars and the Universe and relativity; the discussions in these chapters are of necessity rather abbreviated, and the same comment can be made concerning the author's discussion of radio astronomy and artificial satellites. Inglis gives many useful suggestions for further reading at the end of each chapter; a large fraction of these are the unusually good popular expositions found in the *Scientific American*. The most serious mistakes I found are his figure on page 378 which explains the fine structure rather than the hyperfine structure of hydrogen and on page 420 where he falls into an old trap when he states: "All distance measures are ultimately based on the heliocentric parallaxes of the nearer stars." This is not true, for example, of the derived distances for the Hyades moving cluster or for the Crab Nebula, or more important, for all cepheid distances or for all very large distances based on the luminosities of these pulsating stars. Up until quite recently the cepheid distances were based entirely upon the motions of a few close cepheids and not upon their trigonometric parallaxes or the parallaxes of any other stars.

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Good Science Writing

Guy Murchie's book, **Music of the Spheres** (Houghton Mifflin, Boston, Mass., 1961. 644 pp. $6.95), can only be described as a remarkable accomplishment; it is some of the best popular science writing I have encountered, and there is scarcely a dull page in the book. It should become a best seller, especially if published as a paperback in two volumes. Although the writer has not been trained as a professional scientist, he exhibits a broad knowledge and understanding of astronomy, physics, mathematics, and the history of science. The writing is colorful and imaginative, and the author's more than 450 drawings add substantially to the reader's understanding and enjoyment. The book is in two parts: (i) Moons of Rock and Suns of Fire and (ii) Fields in Space, Deeps of Time. Five of the 14 chapter titles are: "Out from the breathing earth"; "Into the stomach of space"; "Gadflies of the void"; "The netherrealm of the atom"; "The sinews of reality." Every second page has a title of its own, and let me further illustrate both the flavor and content of the book with some choice samples: In the footsteps of the fish; Maneuvers in nothing; Crumbs of passing comets; Twenty billion cosmic snowballs; Skeleton of the galaxy; The strange emptiness within; Atom breezes that blow in solids; The birth and death of particles; The atom as a plucked string; Wisdom in the inward parts; Spectral footprints; A hole in nothing is something; Distance is a flexible dimension; Can time reverse itself?; The apple's view of Newton; Proof by weighing starlight.

Popular science writing, even at best, is often beset with fuzzy statements, exaggerations, misconceptions, errors of commission and omission, as well as misplaced emphasis. Murchie's book, excellent though it is, is not completely free from such pitfalls. For example, the exciting story of Hubble's great breakthrough, first in determining distances to the nearer spirals and then in measuring distances out to the edge of the observable universe, is not told—or explained. Humason's great observational contribution to the expansion of the universe (the red shift) is not mentioned. The author's account of Martian "canals" and "vegetation" is refreshingly conservative compared with that of many popular science writers, but I would have liked more emphasis on the fact that atmospheric oxygen has not been detected on Mars and that its *upper limit* is 1 percent of our own supply, and also on the fact that the Martian green areas are definitely not due to chlorophyll. Perhaps I am too critical on these points, but I have just read a story published in a magazine of wide circulation, in which some earthlings, who have crash-landed on Mars, apparently had not the slightest difficulty in setting up housekeeping. One wonders just how many seconds a man who forgot to bring along his own atmosphere would live on Mars. The rotation period of Venus, given as 22 hours and 17 minutes as derived from radio observations, is almost certainly incorrect. Such a fast rotation would have been measured by available optical instruments, and this planet must have a much longer period of rotation. The temperature of Venus as determined by radio astronomers is close to 600 degrees Fahrenheit; this is not mentioned. Murchie incorrectly states that all elements in the solar interior break down into protons, electrons, and alpha particles. Heavier nuclei are undoubtedly present, and their relative amounts are of critical importance in stellar interior models. Von Weizsäcker's theory of the birth of the solar system is neither as convincing nor as widely accepted as the book indicates.

On page 163 it is stated "a recent map shows every visible star out to an average distance of 2,100,000,000,000,000,000,000 miles from Mount Palomar." For the benefit of those who get lost in the zeros, this distance is 360 million light years—very roughly one-tenth of the radius of the observable universe. I know of no single star that has been observed or mapped even at 100 million light years, and there must be thousands of as yet undiscovered stars closer than a mere 100 light years. Further, a 200-inch exposure might well record more than 10 times as many "new" stars in our own galaxy as are visible on the Palomar Sky Survey, which was made with the 48-inch Schmidt telescope. Another incorrect statement refers to the supernova of A.D. 1054 (now the Crab nebula) as perhaps "the brightest celestial object, other than the sun, ever to be beheld by historic man." The author has forgotten about the moon and a number of very bright comets. In terms of *absolute* luminosity, this supernova, compared with the more than 50 other known supernovae, is one of the brightest, but many galaxies are known that are at least 10 times brighter. On page 583 Mercury's perihelion is said to be stationary in a Newtonian orbit and to advance in an Einsteinian orbit. Actually, the perihelion point advances at the rate of 573 seconds of arc a century; the rate predicted by Newtonian theory on the basis of perturbation by other planets is only 43 seconds of arc less.

Murchie proposes names for the eight fainter satellites of Jupiter: Iodama, Carmanor, Arion, Psylla, Cyrene, Antiphus, Autonoë, and Hecabe. I can only heartily agree with the comment of Seth Nicholson, discoverer of four of these moons, who is quoted as saying: "The names you suggest . . . are good logical ones. I thank that, like Pullman cars, they will be known by their numbers, not their names." He Autonoë!

Colliding Galaxies

Murchie, along with the other authors to varying degrees, does not have a completely satisfactory discussion of radio sources or, especially, of the cosmological importance of Cygnus A and similar colliding galaxies. Inasmuch as tens, if not hundreds, of millions of dollars are now being invested in instruments necessary to further investigate such radio sources, it might be well to discuss the matter here briefly. By 1952 the five brightest sources, or radio "stars," had been identified with five different kinds of objects: a pair of galaxies in collision, an elliptical galaxy with a peculiar jet, a strange object which is possibly an elliptical and spiral galaxy in collision, a supernova remnant (the Crab nebula), and an unusual new type of galactic nebula. At the present time we know (with some certainty as to their positions) of approximately 2000 radio stars; only about 70 of these have been optically identified. Perhaps only a fraction of them will ever be identified for the following reasons. Cygnus A is the second strongest known radio star, yet is at a distance of about 500 million light years and is only 18th magnitude optically. If it were four magnitudes fainter (a factor of

40), it would be almost impossibly difficult to identify or investigate with the 200-inch Palomar reflector by present techniques. Radio telescopes have increased in sensitivity so rapidly that radio stars 1/10,000 as energetic as Cygnus A will be detectable with confidence. A Cygnus A type object, other things being equal, therefore could be detected at distances 100 times greater (50 billion light years!), corresponding to a volume of space 1 million times larger. We might therefore expect 1 million such radio stars to be detectable, remembering that this is a gigantic extrapolation from vanishingly "thin" statistics. Further, Cygnus A is receding with a velocity of 5.6 percent the velocity of light, so that relativistic effects should be overwhelming at the limit of detection, and counts of radio stars to fainter and fainter limits might well give fundamental information concerning the nature of the physical universe out to distances of at least an order of magnitude larger than is possible by present optical means.

However, there is still the all-important question of the identity of these otherwise invisible sources, and for this reason every possible means should be explored to increase the sensitivity of *optical* telescopes. This could come about through image-tube devices, or more sensitive fine-grain photographic emulsions, or the discovery of observatory sites with exceptionally good seeing, or, most important, through the building of larger reflectors. The Russians are building a 236-inch reflector, possibly to be in operation by 1967; there are no corresponding plans in this country. Further, the Southern Hemisphere is poorly taken care of insofar as this problem is concerned, with nothing larger than 74 inches now available.

Measuring Large Distances

There is a strong tendency for most writers on astronomy, whether for popular or for more serious consumption, to write glibly about distances of millions or billions of light years without giving their readers a lucid and reasonably detailed account of just how such enormous distances are measured, what uncertainties are involved, or the basic assumptions that are made. A distance of 5 billion light years, close to the limit of the 200-inch telescope, is up by a factor of more than 1 million compared to the limit of trustworthy distances that can be obtained by the straightforward trigonometric method which uses the diameter of the earth's orbit as a baseline. Although an adequate account should lean heavily on drawings and pictures, perhaps the technique can be at least indicated here by a series of appropriate questions and answers: (i) How far away could the sun be observed with the naked eye? The answer is about 50 light years; this involves a knowledge of the sun's apparent magnitude and distance, the knowledge of the apparent magnitude of a barely visible star (sixth magnitude), and the use of the assumption of the inverse square law which states that the intensity of a source varies inversely as the square of its distance. (ii) How far away could a star like the sun be seen with the aid of a 200-inch telescope? About 50,000 light years. This comes from the fact that the 200-inch telescope has 1000 times the diameter of the pupil of the human eye and therefore has 1 million times the area or light gathering power; again, the inverse square assumption. (iii) How far could a large galaxy with an integrated luminosity of 10^{10} suns be seen through the 200-inch? The inverse square law is again invoked and the answer is 100,000 times further out, or 5 billion light years. (iv) What does the astronomer have to know in order to "measure" such a distance with some degree of confidence? Three things are involved: identification, photometric measurement, and calibration. The observer must be able to identify accurately a smudge on a photographic plate as a large galaxy of a given absolute luminosity. He does this by fixing his attention on a few of the brightest galaxies in a distant cluster of galaxies—each of the few dozen smudges verifying the identity and relative luminosity of each of the other neighboring smudges. The measurement is a laborious process of photometry, attempted only on those rare moonless nights of superb seeing. The light from the perhaps invisible galaxy is isolated in the focal plane of the giant reflector by a hole a few seconds of arc in diameter, accurately positioned by means of offset guiding from a brighter star. The tenuous mixture of galaxy light and night sky light is allowed to fall on a sensitive photoelectric surface, and the resulting emitted electrons are electronically counted one by one. The observer must shift back and forth all night long between the galaxy and an adjacent bit of clear sky so that the light from the galaxy can be accurately disentangled from the much more intense night sky radiation.

The astronomer then asks the key question: "How far away must this galaxy be to appear as faint as it does?" Before he can answer he must know the absolute luminosity of a large galaxy—whether it is 10^{10} suns or something smaller or larger. This involves three successive stages of calibration. The cepheid variables, those supergiant milestones of the universe, betray not only their own presence in neighboring galaxies by their characteristic variation of light but also their own absolute luminosity which increases with the period of light variation. This cepheid calibration is indirectly accomplished by statistically deriving the mean distances of nearby cepheids from their characteristic motions, or it is obtained from those few cepheids which are members of relatively nearby galactic star clusters of known distance. For galaxies of intermediate distance, such as those in the great Virgo cluster of galaxies, the cepheids are too faint to be observed, so the brightest supergiant stars in a galaxy must be used. This bright star luminosity calibration is obtained from neighboring galaxies whose distances are known because of the cepheids they contain. This large sample of intermediate galaxies of known distance (and therefore of known integrated luminosity) can then be discussed in terms of the statistics of their integrated absolute luminosities—the so-called luminosity function. The third and last calibration step enables the astronomer to predict with some confidence just what the average absolute luminosity of the 5 or 10 brightest galaxies in a cluster of galaxies will be.

The patient reader who has followed the thread of logic through all of this can readily understand how identification errors, calibration errors, statistical errors, photometric errors, and errors of assumption can enter at every stage of the game. He will not be surprised to learn that Hubble's old distance scale is off by a factor of somewhere between 2 and 15; or that a much more precise value of this factor will not appear overnight. There are other possible approaches; the apparent diameters of galaxies and also the photometry of globular clusters associated with galaxies can give useful checks. The linearity of the relation between the red shift and the photometrically derived distances gives some confidence about the internal consistency of the cosmological distance scale and also provides a useful method of determining the distance of an isolated galaxy by spectroscopic observation of its velocity; it does not verify the slope of the velocity-distance relation.

Astronomical History

Colin A. Ronan's **Changing Views of the Universe** (Macmillan, New York, 1961. 206 pp. $3.95) is for the serious amateur and student; it is designed to provide a historical background against which the contemporary picture of astronomical research may be compared. Prehistory, early civilizations, Greek ideas, and the growth of astronomy in Western Christendom are well explained and make for good reading, although the book as a whole suffers from a dearth of explanatory drawings and pictures. The stature of Hipparchus, probably the greatest observational astronomer of antiquity, is clearly shown. A good modern biography of this great man would be most welcome. The stagnation of astronomy after the work of Ptolemy is a peculiar affair. A final death blow to Greek astronomical ideas and accomplishments occurred in A.D. 640 when the Mohammedan fanatic, Caliph Omar, ordered the destruction of the Alexandrian library. One might well ask, is it possible for such a thing to happen again?

The importance of the impact of technological developments such as the telescope is well emphasized: for example, "Photography brought the truly achromatic reflector back into favour, and it would be no exaggeration to say that the advent of spectroscopy and photography virtually changed the face of observational astronomy, as well as certainly having a profound effect upon cosmological speculation." It has often been said that technology depends on basic science; the reverse can also be true. Astronomers now study distant stars and galaxies in a variety of new ways because of highly developed and complex vacuum tubes, or multiplier phototubes, or, in the future, rockets.

The last chapter—"The twentieth century"—is unfortunately a real disappointment and mars an otherwise excellent book. A volume entitled *Changing Views of the Universe* should end with an adequate picture of what we *now* know about the universe and of how we learned these things. The great 20th century developments are given in the last 30 pages in vague or scrambled form or not at all. Shapley's great "leap of faith" which drastically changed our viewpoint from heliocentric to galactocentric is not described. The measurement of cosmological distances is not given nor is the greatest observed velocity of recession (now up to 46 percent of the velocity of light). Although there are a considerable number of pages on relativity and English cosmological speculations, there is but one sentence on the Lemaitre-Gamow "Big Bang" hypothesis and little or nothing on current ideas of stellar evolution. The exciting probable future history of the sun for the next 6 billion years is not given; an excellent account of this can be found in Stokley's book. The accomplishments and implications of radio astronomy are poorly presented. Half a sentence is devoted to 21-centimeter (hydrogen) radiation and nothing at all to colliding galaxies or radio signals from Jupiter or to radar contact with the Moon, Sun, and Venus. The definitions in appendix 5 for right ascension, celestial longitude, and stellar parallax are incorrectly given.

Galaxies Again

Harlow Shapley's contributions to astronomy over the past half century are numerous and fundamental. His discovery of the size of our galaxy and of the position of its distant center was one of the truly great accomplishments of this century. Shapley is also a successful popular writer, and his revised edition of **Galaxies** (Harvard University Press, Cambridge, Mass., 1961. 186 pp. $5), one of the Harvard Books on Astronomy, should sell well. In the 18 years since publication of the first edition large new optical telescopes at Lick, Palomar, Pretoria, Canberra, and Harvard Kopje have made notable contributions in this field; some of these are presented in this edition, but a great deal of current progress is omitted. As the author states in the preface, the contributions from radio telescopes, the motions of spiral arms, the new color-luminosity arrays for globular clusters, red-shift details, and new views on the ages and evolution of stars and galaxies are treated briefly or not at all. The new edition includes a number of the recent best photographs taken at Palomar or with the ADH Schmidt in South Africa. The discussion is essentially nonmathematical because, although it has often been found necessary to investigate the solar system with a ten-place electronic calculator, a 10-inch slide rule still suffices for most calculations in the realm of the galaxies.

Summary

Shapley's book is the only one of the seven which will be of substantial assistance in the training of astronomy students at the graduate level. Although a number of excellent advanced monographs are now available or are in the making, textbooks on the junior, senior, and first-year graduate level are sorely needed.

The other volumes will be useful, in one way or another, to students and in informing the general public about astronomy. Both Schneider's and King's volumes will be helpful at the junior-high and high-school levels, and they will also be of interest to the general public. The volumes by Stokley and Inglis will probably find their greatest use at the beginning college level. *Music of the Spheres* is thoroughly enjoyable reading and should become a popular classic. Ronan's book, except for the shortcomings of the final chapter, gives a readable and well-balanced account of astronomical history.

Avian Functional Biology

Biology and Comparative Physiology of Birds. vol. 2. A. J. Marshall, Ed. Academic Press, New York, 1961. x + 468 pp. Illus. $14.

This volume contains 14 chapters, which, together with the 12 chapters of the first volume, offer the reader a comprehensive, carefully selected, and well-presented account of the functional biology of birds. As in the first volume, each chapter deals with a discrete subject and has a useful bibliography which readily enables non-