

ASTRONOMERS

in TURMOIL

By Otto Struve

THE great upheaval in science, which began with chemistry and physics a quarter of a century ago, has recently penetrated the field of astronomy and caused a state of turbulence, uncertainty, and chaotic expansion unknown in the history of mankind. On October 4, 1957, the first Russian sputnik was thrust into an orbit around the earth and the words "exploration of space" replaced the ancient word astronomy.

The explosion which we are witnessing today is mainly due to the sudden recognition by our people of the importance of what the popular writers call the conquest of space. It is characterized by the creation of large research centers such as those controlled by the National Aeronautics and Space Administration and the National Science Foundation and by government spending of very large sums of money for the support of research and training of personnel. This expansion in terms of large and expensive research tools cannot by itself generate a corresponding expansion in terms of ideas. But I believe that we are in fact living in a period of vigorous, though much more gradual, increase of ideas, which has little or no relation to the sputniks and which began in the early years of this century, through the work of Emden, Schwarzschild, Hale, Kapteyn, Eddington, Jeans, Russell, and many others, and which is still gaining momentum through the work of a dozen or more brilliant astronomers of our own generation. The two overlapping ex-

pansions produce an impressive flow of new knowledge. But will a future historian be able to apply to our era what C. P. Haskins has recently said about the age of Newton: "Surely there has never been a greater period in the history of science than that of Newton. The time of his most important work, the mid-seventeenth century, has perhaps never been surpassed in the sheer brilliance and variety of its intellectual and cultural contributions. These were the years of the founding of the Royal Society and the French Academy, and of the works of a host of brilliant innovators in fields ranging from science through literature and all the arts."*? Or will he be more impressed by the purely technical side of mid-twentieth century science, by the team work of many competent but not especially brilliant scientists, by the evident confusion of ideas, by the competitive aspects of our research and its political overtones?

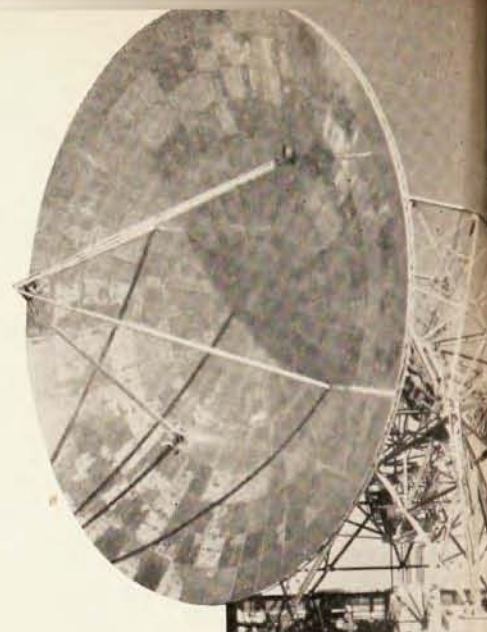
Let us consider some of the effects of this rapid transformation.

The Number of Astronomers Is Inadequate

WHEN I arrived in the United States in 1921, I was for several years the only graduate student at the Yerkes Observatory of the University of Chicago, then and now one of the largest departments of astronomy in this country. The number of astronomy PhD degrees in the United States was between five and ten a year in the 1920's and about fifteen in the decade following the end of the second world war. Assuming, rather generously, that all PhD's remain active in astronomy, and that their average useful lives as research workers are of the order of thirty years, we should have had an equilibrium population of about 225 astronomers in the earlier period and about 450 in the more recent decade. These estimates include all who were qualified to receive a PhD degree. The number of active astronomers without this degree was and is almost negligible. It is reasonable to estimate that about ten percent of the total number (22



Otto Struve, whose father, uncle, grandfather, and great-grandfather were all astronomers, was born in Russia and came to the United States in 1921. He became the National Radio Astronomy Observatory's first director in July 1959, after having directed the University of California's Leuschner Observatory for the previous ten years.



* Report of the President, Carnegie Institution of Washington, Year Book, 1958-59, and Bull. Atomic Scientists 16, 146 (1960).

e 85-foot Howard E. Tatel radio telescope at National Radio Astronomy Observatory, Green Bank, West Virginia, is the first of several telescopes to be available to research scientists at Green Bank.

in the 1920's and 45 in the interval from 1945 to 1955) were sufficiently capable of making important contributions to knowledge.

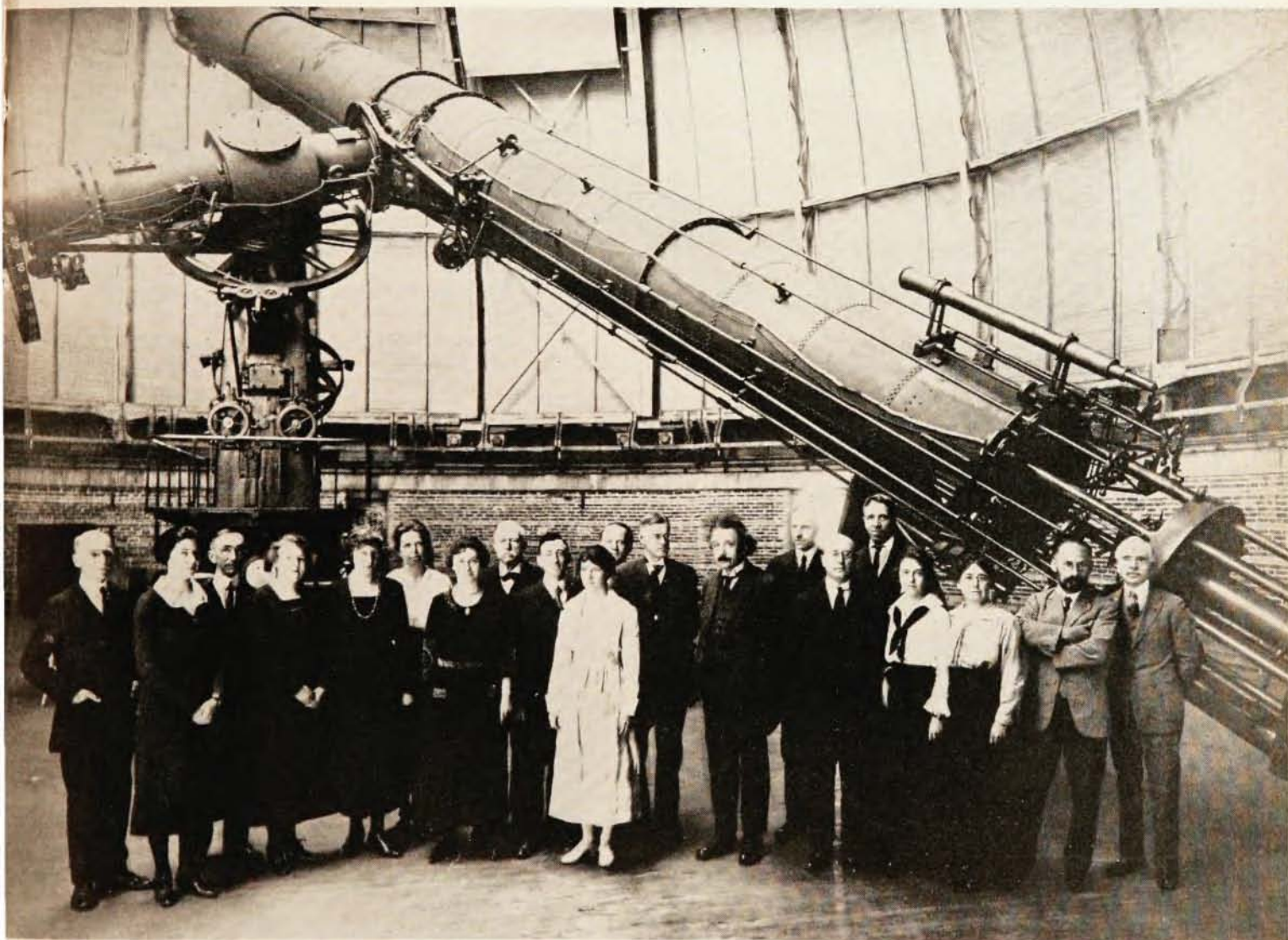
Today all departments of astronomy are understaffed, and there is a tremendous demand for trained astronomers in special laboratories, government agencies, and industrial firms. Almost every issue of *Physics Today*, *Scientific American*, *American Scientist*, etc., and even of the more popular mass media, contains advertisements offering new and attractive opportunities to competent astronomers.

Efforts are, of course, under way to train more astronomers. We may expect that in the 1960's the number of PhD's in astronomy will be doubled, or even tripled, and by 1970 an equilibrium population of about 1350 should be reached.

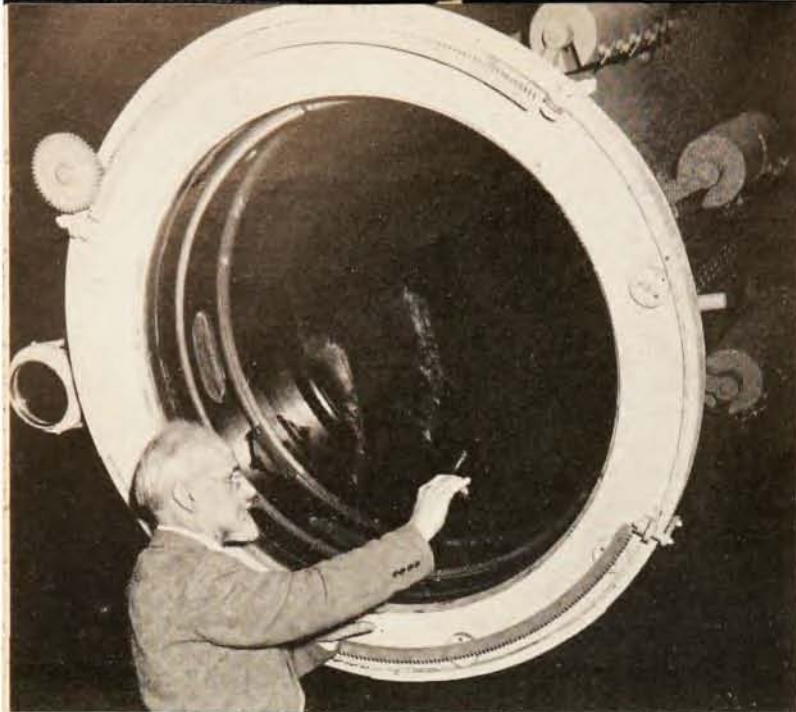
The demand, however, will exceed this number by a factor of two or three and there is no indication that the universities will be able to supply the required number. The immediate result of the shortage is twofold:

(a) There is unquestionably a tendency to lower the standards. Almost every observatory director or departmental chairman is faced with the alternative of leaving positions vacant or of hiring a person whom he would not have considered qualified a few years ago.

(b) Fortunately, there is a growing tendency among



1921 photograph was taken when Albert Einstein visited the Yerkes Observatory of the University of Chicago at Williams Bay, Wisc. Visitors and staff posing with 40-inch telescope, from left to right: Storrs B. Barrett, Lela D. Cable, John A. Parkhurst, Elsie E. Johnson, Dorothy W. Block, Florence B. Lee, Dorothy K. Sullivan, Edward E. Barnard, A. J. Dempster, Harriet M. Parsons, A. C. Lunn, Edwin B. Frost, Albert Einstein, A. Pfueger, S. Ginsberg, Oliver J. Lee, Esther L. Searles, Mary R. Calvert, George Van Biesbroeck, and George C. Blakslee.



George Van Biesbroeck stands in front of objective lens of 40-inch refracting telescope at the Yerkes Observatory.

physicists to recognize that astronomy is a part of physics, and we may hope that the gap between demand and supply will be closed by the relatively small number of physicists who have become interested in astronomy and have, for all practical purposes, become astronomers.

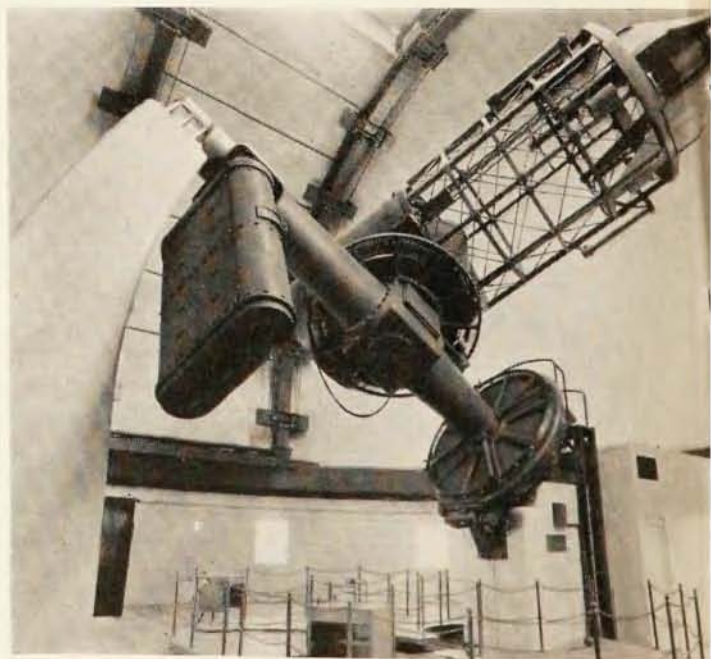
Astronomy Is a Part of Physics

UNTIL the latter part of the 17th century there was no clear-cut separation between astronomy and physics. Newton was a natural philosopher—he was as much astronomer as physicist. The separation between the two sciences resulted from the fact that the great maritime powers, especially Great Britain and France, found it necessary to stimulate work in the field of navigation—especially with regard to the determination of longitudes at sea. The great national observatories, at Paris in 1671 and at Greenwich in 1678, were founded to deal with this practical problem, and most of the other national observatories were also charged with navigational and geodetic tasks. Although from the very beginning the astronomers connected with these national observatories devoted a large part of their time to the exploration of the physical properties of celestial bodies, the purely practical tasks remained for a long time in the foreground. The construction of astrophysical observatories in the second half of the nineteenth century only partly removed the separation; the large telescopes required for astronomical observations, the geographical and climatic requirements of an observatory, and the very nature of astronomical research (observation versus experiment) all differed so much from the work of a physicist in a laboratory or university office that the separation, of necessity, continued. But at the present time the instrumental facilities in physics are so varied that there is no longer any obvious need to consider an

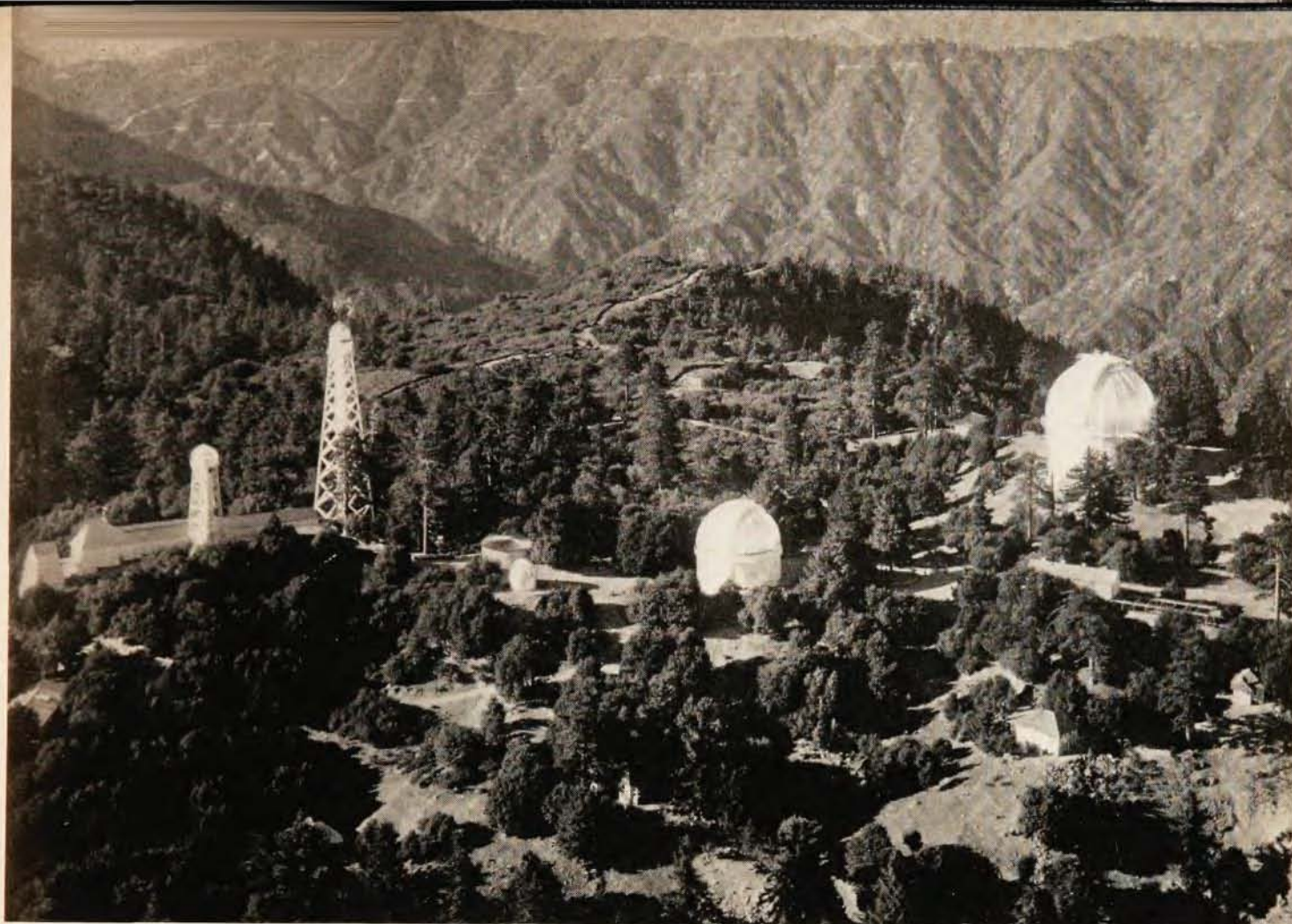
observatory a different kind of institution from a modern physical laboratory. Moreover, experimentation has become an accepted practice of at least the space astronomers, and observation is to some extent the practice of a cosmic-ray physicist or a physicist working with a large nuclear accelerator. Thus there is every reason to regard astronomy as an integral part of physics.

Conservatism in Old-Style Astronomy

IT is my impression that until about forty years ago the astronomers were among the most conservative scientists in the world. They were (with a few notable exceptions) relatively unreceptive to new and revolutionary ideas and they preferred to work on such necessary but unexciting tasks as the accurate determination of star positions on the celestial sphere (for the derivation of proper motions), the accumulation of large numbers of stellar radial velocities (for the determination of the solar motion), etc. These and other similar studies are unquestionably of vast importance. Without them we would now lack the solid astronomical foundation upon which rest all the exciting new results of the "space age". Nevertheless, I recall that as a student of astronomy I had from the beginning misgivings about ever being happy in spending all or most of my time observing the transits of stars through a meridian-circle telescope, and I sometimes felt discouraged when I considered my outlook as a scientist who might after many years of work publish a catalogue of stellar coordinates that would yield interesting results only to an astronomer of a later generation, compared with the exciting work



Parabolic reflector of McDonald Observatory of the University of Texas, operated jointly by the Universities of Chicago and Texas.



General view of Mount Wilson Observatory in California (altitude, 6000 feet) shows Observatory's two solar towers and the domes of the 60-inch and the 100-inch telescopes.

of a physicist or chemist who could reasonably expect to harvest the fruits of his investigations during his own lifetime.

Recently I reread the abstracts of papers presented at the 1910 meeting of the *Astronomische Gesellschaft*, the only international organization of astronomers at that time. Among the sixteen contributions, only one is of interest today, namely, Elis Strömberg's "On the Cosmogonical Significance of Comets", and only one other dealt with what we would now call astrophysics, namely, J. F. H. Schulz's "On Solar Physics". But while Strömberg's work represented an almost prophetic vision of the development of cosmogonic theory, nearly every statement by Schulz was wrong (not necessarily his fault). The minutes of the meeting succinctly report: "Eine Diskussion findet nicht statt."

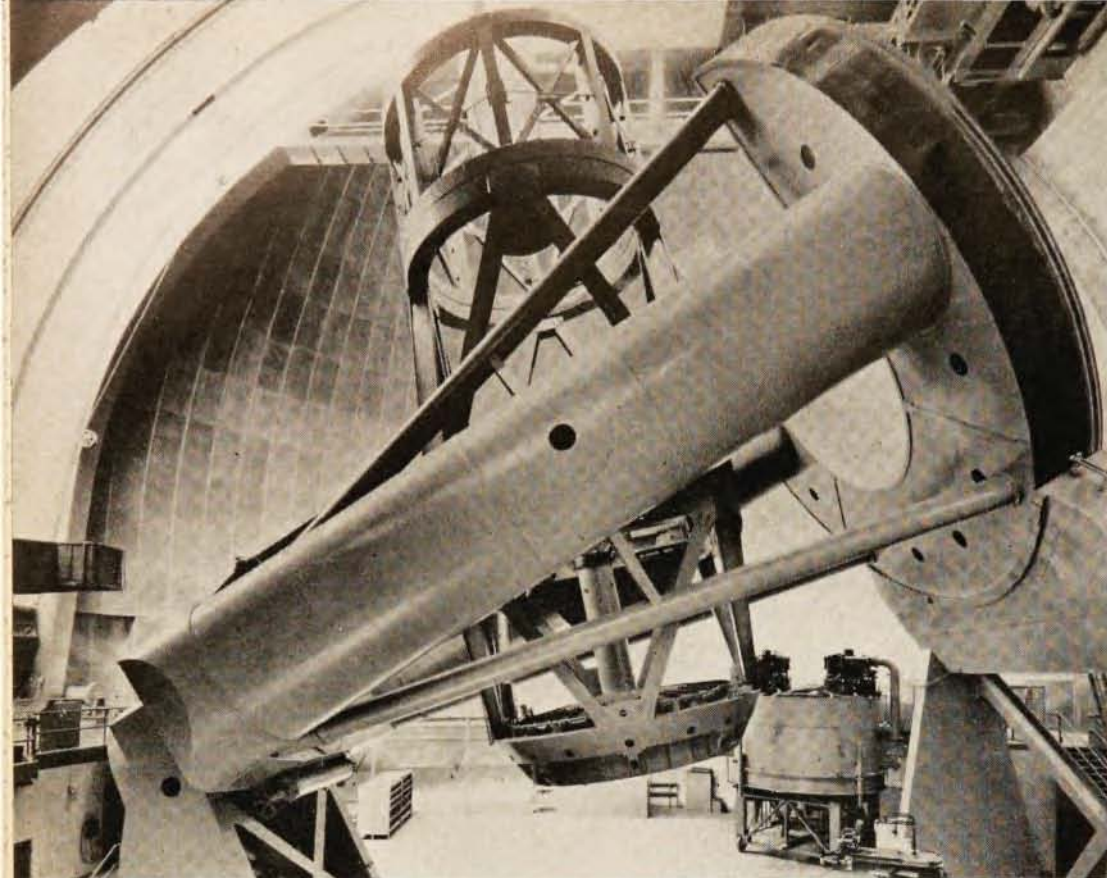
"Let's Be Practical About Space"

THE first (May, 1960) issue of the new and somewhat flamboyant *Space World* magazine contains an article under this title by John R. Pierce of the Bell Telephone Laboratories, which suggests that "our alleged space program needs a tightening up of all its bolts—and the elimination of all nuts." He writes (and I agree with him) that he is "shocked that when disproven fallacies of space travel appear and reappear in seemingly respectable newspapers and jour-

nals no one so much as lifts an eyebrow. Indeed," he says, "the way to fame appears to be the propagation of the big error, and a fantastic story suffers only from the competition of one still more fantastic. And even on high levels, too much of this unrealistic wool-gathering is going on."

There is no doubt that the astronomers as a group (again with important exceptions) have become too receptive to all kinds of more or less fantastic ideas. I do not like to mention names of projects or theories, but I could draw up a list of purely astronomical items that would parallel the twelve items on space travel chosen by Pierce to illustrate their importance in descending order, from those he regards as a "must" to those that are "marginal to crazy".

But I believe that our frequent preoccupation with marginal or crazy projects is a reaction to our former conservatism; also that some ideas which now seem marginal may not appear as such in future years (when I was a student discussions of any form of life on Mars or Venus were not in good repute, nor was it safe for a student to take an interest in Eddington's estimate of twenty million degrees for the central temperature of the sun). Some marginal or even crazy ideas have appeared to me, and probably to others, as extremely stimulating to the mind. It is necessary to understand that in the entire history of astronomy, the oldest of



The world's largest optical telescope is the 200-inch Hale reflector at Mount Palomar Observatory in California. The Mount Palomar facilities are operated jointly by the California Institute of Technology and the Carnegie Institution of Washington.

the sciences, there has never been a period of turmoil equal to the one we are witnessing today, and that it is inevitable that in this period, for which we were so appallingly unprepared, the distinction between sound science and pseudo science should become even more vague than it was in the days when Augustus de Morgan wrote his famous *Budget of Paradoxes* (1872).

Project Ozma *

ALTHOUGH it is poor taste to discuss marginal problems by others, I need not have any inhibitions in talking about project Ozma, for which I, as the director of the National Radio Astronomy Observatory, carry administrative responsibility. This project has been given an unreasonable amount of publicity, often incorrect or distorted and always with the wrong emphasis. It has aroused more vitriolic criticisms and more laudatory comments than any other recent astronomical venture, and it has divided the astronomers into two camps: those who are all for it and those who regard it as the worst evil of our generation. There are those who pity us for the publicity we have received and those who accuse us of having invented the project for the sake of publicity.

Let me state at once that as far as the publicity is concerned, I alone am responsible. I mentioned the project, rather casually, in one of my Karl Taylor

Compton lectures last November at the Massachusetts Institute of Technology. I assumed then, and I believe now, that the American taxpayer has a right to know what is being done with his money, provided there are no security aspects. The question is not whether I am right or wrong, but whether the experiment is good or bad. I can only describe as shameful any thought that we ourselves are seeking publicity: in forty years of astronomical research I have almost never been pleased with publicity which I have received, and in nine cases out of ten I have felt embarrassed by it.

The hypothesis of the existence of intelligent life beyond the earth is almost as old as astronomy itself. The Greek satirist and poet Lucian expounded it, in about 150 A.D., and so did Rabelais, Swift, Voltaire, and many others. De Fontenelle's *Entretien sur la pluralité des mondes* (1686) was a famous book for many generations, and served as a source of inspiration to Lomonosov and his contemporaries. In 1900 E. S. Holden reprinted an article by G. M. Searle entitled "Are the Planets Habitable?" But these early speculations were devoid of scientific considerations, except for the following remarks by Searle: "Neither can we tell whether the other innumerable brilliant suns scattered through space have attendant planets like our sun. But it would be strange if they had not. If any considerable proportion of them have, evidently the chance that there are other habitable worlds in the universe becomes very great."

The origin of project Ozma goes back two or three years when I first learned at a trustees' meeting of the Associated Universities that powerful radio transmitters are capable of sending waves to distances of

* The name is that of "the queen of the imaginary land of Oz—a place very far away, difficult to reach, and populated by exotic beings" (F. D. Drake). The purpose of the project was to sweep over the radio spectra of a few nearby solar-type stars, in the vicinity of 1420 mc/sec, with a narrow bandwidth of about 10 c/sec, in order to search for variable sources of radioemission connected with such stars. Such sources, if they exist, could come from the stars themselves (flares) or from their hypothetical planets. In the latter case they could be either of natural origin, like the "thunderstorm" detected in the atmosphere of Jupiter, or of artificial origin.

ten light years, with a flux that could be readily discerned by means of radio telescopes now in existence. It was reasonable to reverse the idea and ask whether it would not become possible to observe with a passive instrument the radio radiation that might be produced artificially on planets revolving around relatively close stars. Among the radio astronomers interested in this problem was Dr. Frank D. Drake of the National Radio Astronomy Observatory who had computed that a signal emitted at a distance of ten light years by means of a radar antenna similar to the one at Millstone Hill could indeed be detected with an 85-foot radio telescope equipped with a sensitive receiver. Other radio astronomers had expressed similar views, and in 1959 G. Cocconi and P. Morrison published an article on this subject in *Nature*.

My own work in astrophysics had long ago convinced me that the number of solar-type stars associated with planets must be very large. I estimate that approximately 50 billion stars in the Milky Way alone possess planets. The total number of planets throughout the observable part of the universe must then be of the order of 10^{20} or 10^{21} . Our answer to the question "Are there planets in the universe outside the solar system?" must be decidedly yes.

The question whether any of these planets are capable of supporting *some* form of life cannot be answered by astronomers alone, but the physical conditions of a planet revolving around a solar-type star at a distance from it of one or two astronomical units must be similar throughout the universe. The astronomers have also shown that the intervals of time during which a solar-type star remains essentially at a constant surface temperature and at a constant size is of the order of approximately ten billion years. Biologists conclude then that these intervals are sufficient to permit living organisms to develop on the planets. The answer to this second question is probably yes.

It is, of course, impossible to give a decisive answer to the question "Are there *intelligent* living beings on any of the many billions of planets?" Opinions may differ. An intrinsically improbable single event may become highly probable if the number of events is very great. If the probability of finding intelligent life on one planet at a given time is substantially greater than 10^{-10} , then it is probable that a good many of the billions of planets in the Milky Way support intelligent forms of life. To me this conclusion is of great philosophical interest. I believe that science has reached the point where it is necessary to take into account the action of intelligent beings, in addition to the action of the classical laws of physics. The physi-

cal properties of the earth have already been drastically changed as a result of human action. The earth is enveloped by radio waves of different frequencies which would be observable from distant points in the Milky Way. There are other phenomena, such as the explosion of atomic bombs, which, if observed from a distance of several light years, could not be explained by the customary application of the laws of physics. This constitutes a drastic and a challenging departure from the past. We have always been able to treat separately what might be described as natural phenomena and phenomena produced by actions of men. The two now begin to overlap and we must re-adjust our thinking.

As I have stated, the probability of observing radio signals from intelligent beings on one of the two or three solar-type stars at distances of the order of ten light years is almost zero. Why then was the experiment performed at Green Bank?

(a) The receivers for this work require special and novel features, described by Drake in *Sky and Telescope*, Vol. 19, No. 3, January, 1960. The development of such receivers should be of value to all radio astronomers.

(b) Experience gained in making the observations will be of value to Mr. Drake and others who are associated with him.

(c) The receivers are also intended for the purpose of measuring the polarization of certain radio sources, such as Cassiopeia A.

(d) The same receivers are used to observe flare stars of the type I have discussed in several previous articles.

(e) There is every reason to believe that the Ozma experiment will ultimately yield positive results when the accessible sample of solar-type stars is sufficiently large.

One of the world's larger radio telescopes is the high-precision 140-foot parabolic dish, the base of which is shown at right, now under construction at the National Radio Astronomy Observatory at Green Bank, West Virginia.

