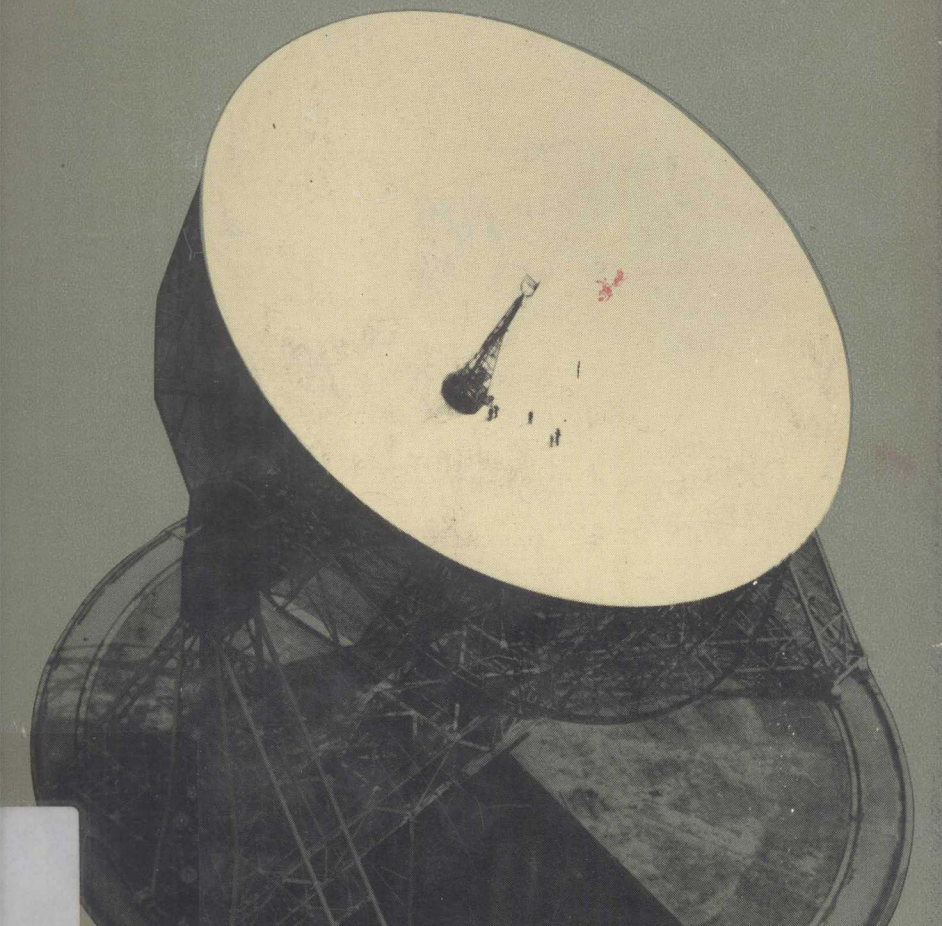
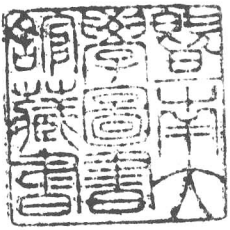
Sir Bernard Lovell

The Exploration of Outer Space



THE EXPLORATION OF OUTER SPACE

SIR BERNARD LOVELL



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NOTE

In this reprint it has been possible to correct a few errors which appeared in the original text. A number of people pointed out that there was an inconsistency between the distances of some of the remote nebulae given in Plate V, and in various parts of the text. These distances have now all been related to a Hubble constant of 100 km/sec/megaparsec. Since the original lectures were delivered, Sandage at Mt. Palomar has published evidence for a Hubble constant as low as 75 km/sec/megaparsec. If future work justifies this value then the distances quoted here would have to be increased by a factor of $\frac{4}{3}$.

A. C. B. L.
June 1963

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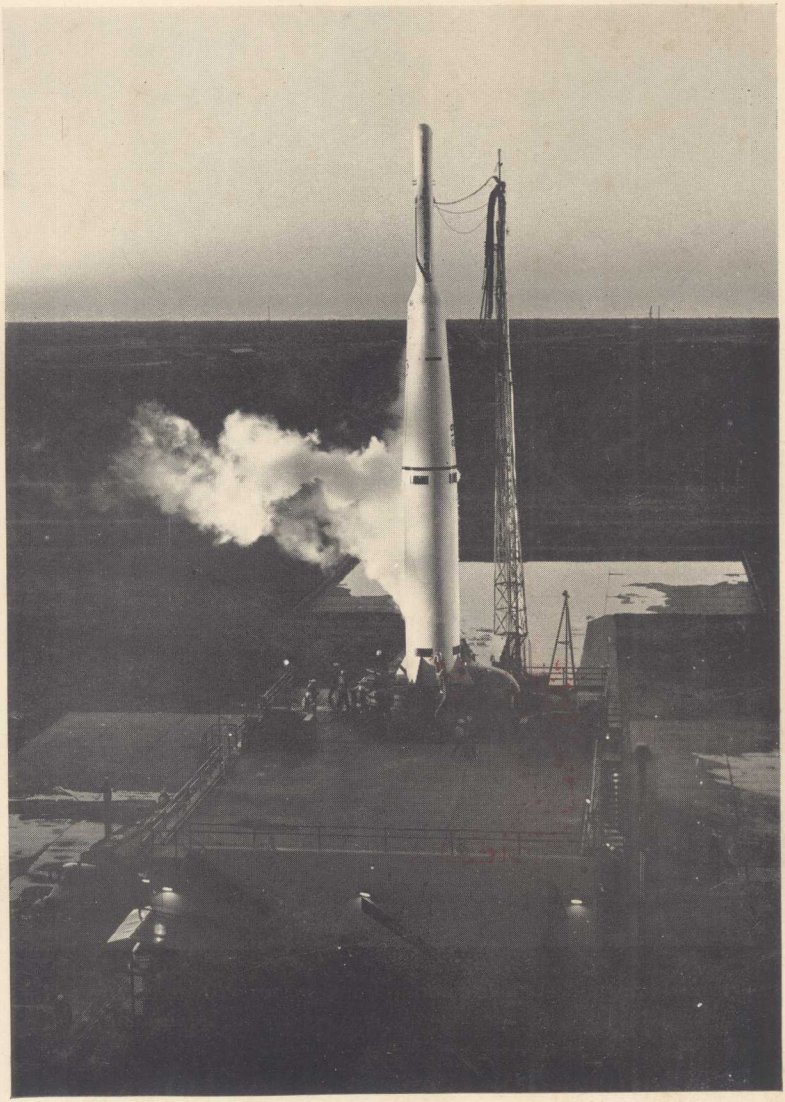


I. The Thor Able rocket combination at Cape Canaveral before the launching of the space probe Pioneer V. (*By kind permission of Space Technology Laboratories, Los Angeles.*)

PREFACE

This book is based on the Gregynog Lectures which I gave in October 1961 in the University of Wales at Aberystwyth under the title of *The Exploration of Outer Space*. The first four chapters are equivalent to the four lectures which were delivered on successive evenings to an audience predominantly consisting of undergraduates. The hall was not adequate to contain all those who attended the lectures and the intense interest of this packed audience under conditions which must have been extremely uncomfortable was, in itself, an inspiration.

The fifth chapter of this book is not based on any specific part of the Gregynog Lectures. During the summer of 1961 I became increasingly obsessed with the dangers of certain developments in space research, and this essay on 'Ethics and the Cosmos' was written before the Gregynog Lectures and has appeared in modified form in the *Sunday Times* and in the *New York Times*. It seemed appropriate to the general subject matter of the book and appears here in its full and original version.

It is not uncommon for lectures to be published, often in the journals of learned societies and sometimes in book form. Frequently the question of publication may be a matter to be decided by the lecturer, but in some cases it may be a condition that the lecture should be published. The Gregynog Lecturer has such an obligation. Some lecturers prepare a script in detail before they lecture and may even read their lecture from it. For them, publication is no burden. I envy them, for I find a script or even extensive notes a burden, and as with many other lectures I found myself with nothing but slides on the eve of the Gregynog Lectures. It was at this point that someone suggested the solution of the tape recorder, and since the recordings of Moon echoes and Moon probe signals were to be played in one of the lectures there seemed no reason why the spoken word

should not be recorded on tape and transcribed directly into book form.

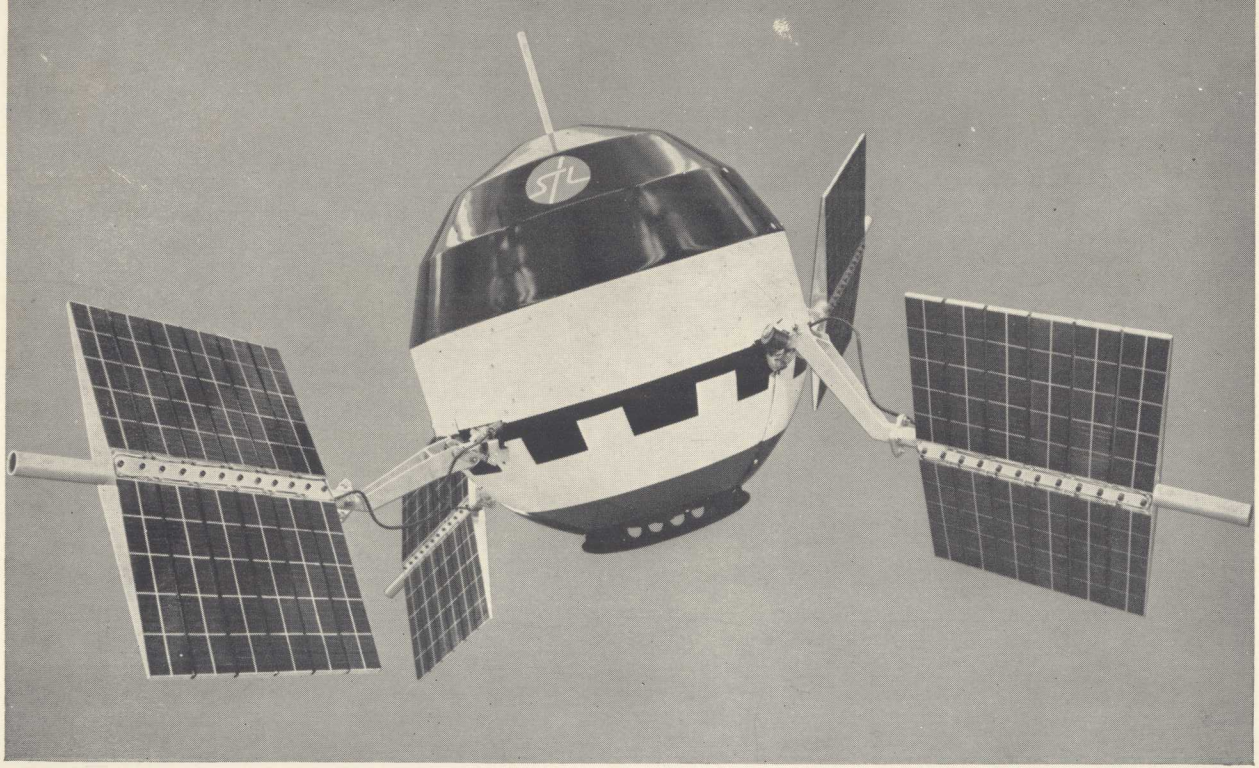
Many years ago after speaking at a scientific meeting and having failed to produce a manuscript, I was asked to approve for publication the copy of my speech made by a stenographer. This typed record was so incoherent—either with sentences which were incomplete, or with sentences begun and then restarted on a different line of thought—that it seemed impossible that it could bear much relation to what I said and it was natural to assume that the stenographer was at fault. Nevertheless in subsequent years, when tape recordings were able to provide a check on secretarial transcriptions, I realized with some dismay that the things I said were not in the precise form which they might have been had they been read from a manuscript—particularly when slides or illustrations were used in the exposition.

Even so, I prefer to see my audience. Unless the circumstances are unusual, or the subject is remote from my daily work, I resent the tie of the manuscript—because I want to study the people to whom I am talking and deal with the subject according to their reactions. In the case of these lectures the spoken word has required a good deal of changing before being ready for publication.

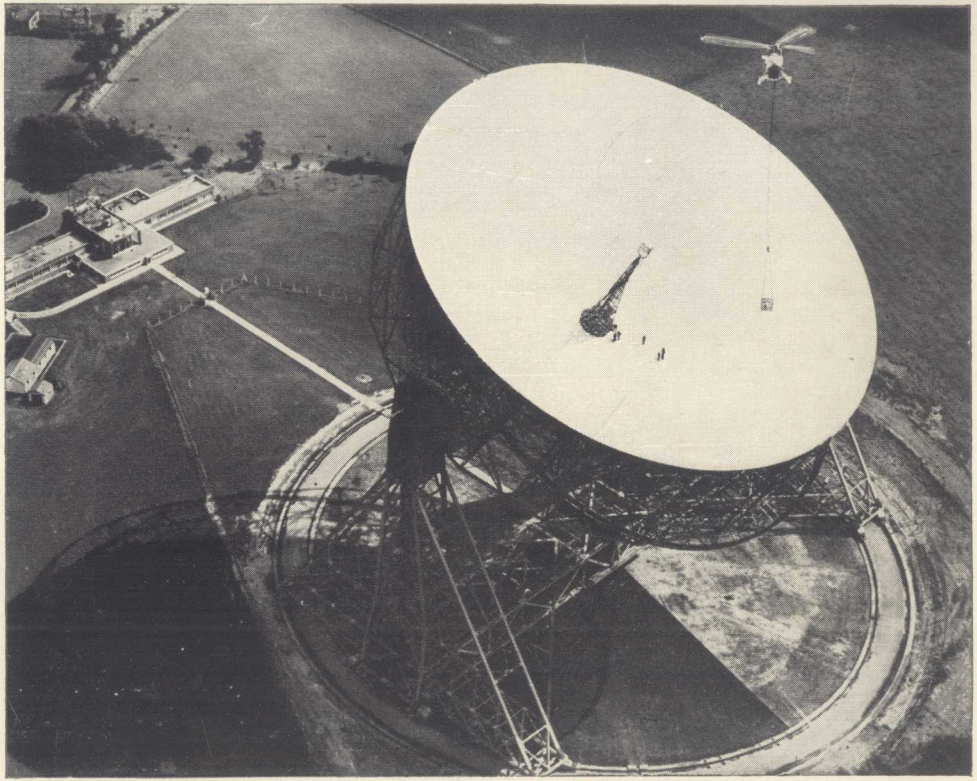
I am extremely grateful to Professor Cocconi of Cornell University for his permission to reprint the letter which he wrote to me in the summer of 1959 and which is published here in the Appendix. I am also indebted to Mr. R. G. Lascelles for his invaluable assistance with the illustrations and to Miss Anthea Hollinshead who had the unenviable task of transcribing the Gregynog Lectures from tape to type and of further interpreting the corrected typescript.

JODRELL BANK
JULY 1962

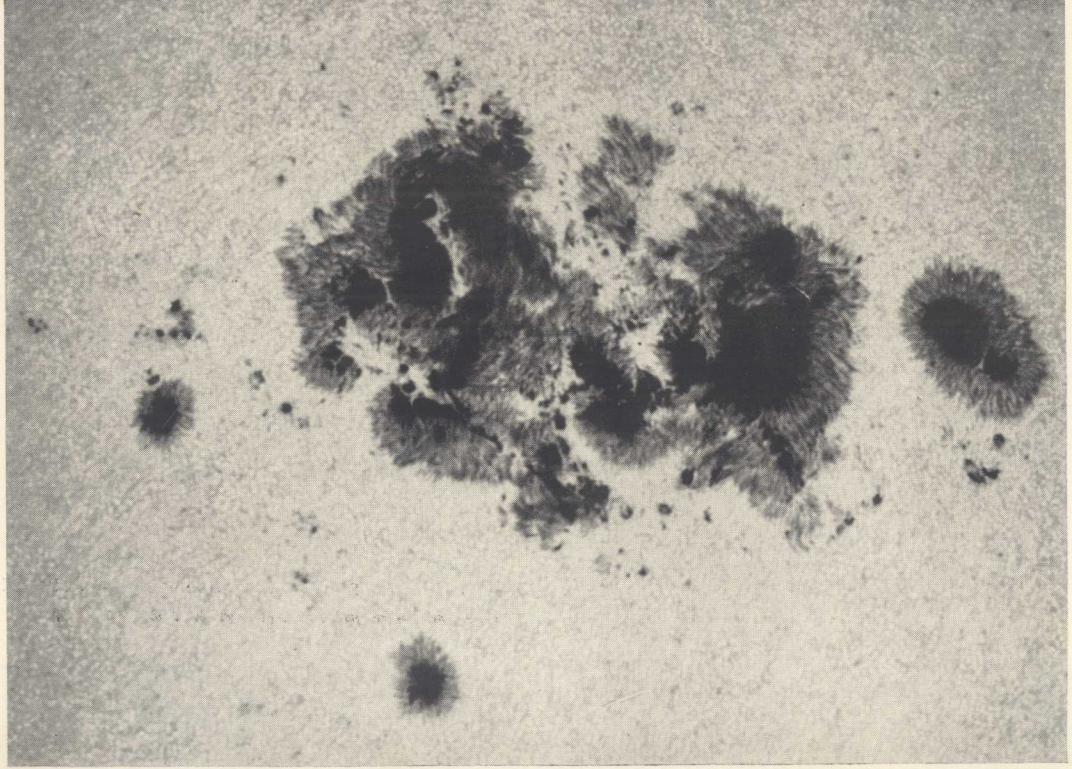
A. C. B. LOVELL



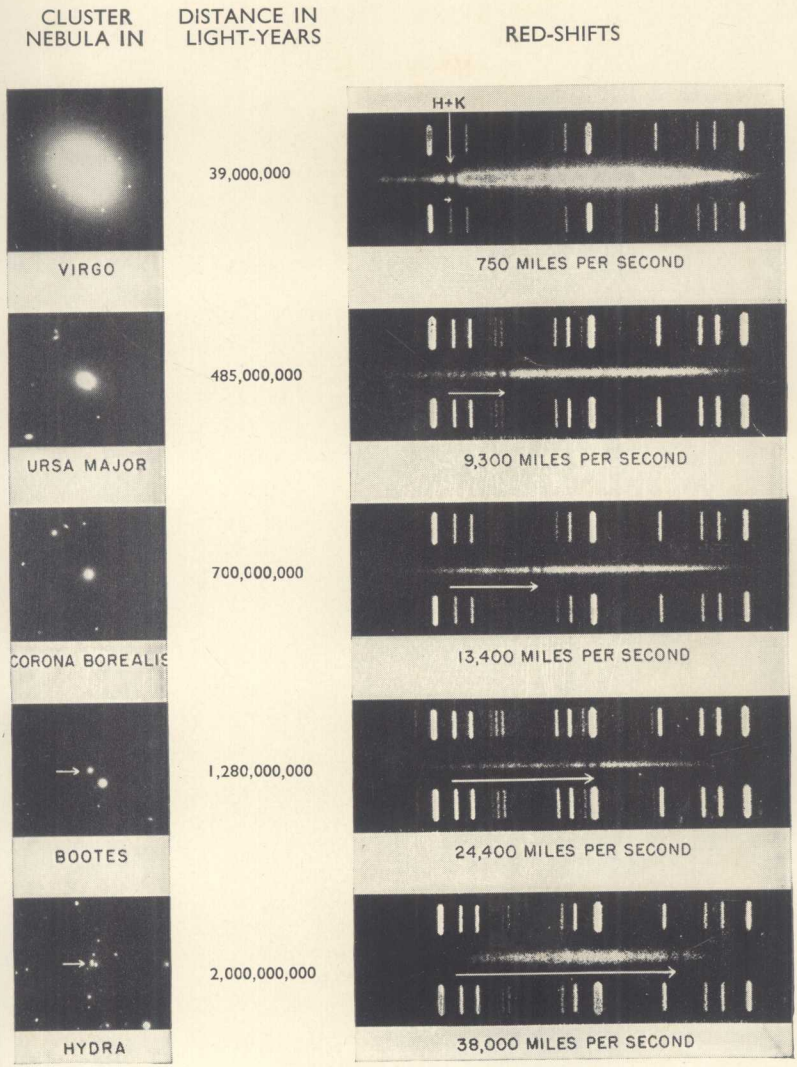
II. The space probe Pioneer V launched on 11th March 1960. This probe was tracked by the 250-ft. radio telescope at Jodrell Bank daily until early July 1960 when it was at a distance of over 22.5 million miles from Earth. (*By kind permission of Space Technology Laboratories, Los Angeles.*)



III. The 250-ft. radio telescope at Jodrell Bank photographed when a helicopter was removing from the base of the aerial mast inside the bowl the transmitter which was used to command the Pioneer V space probe. (*By kind permission of the* Daily Mail.)

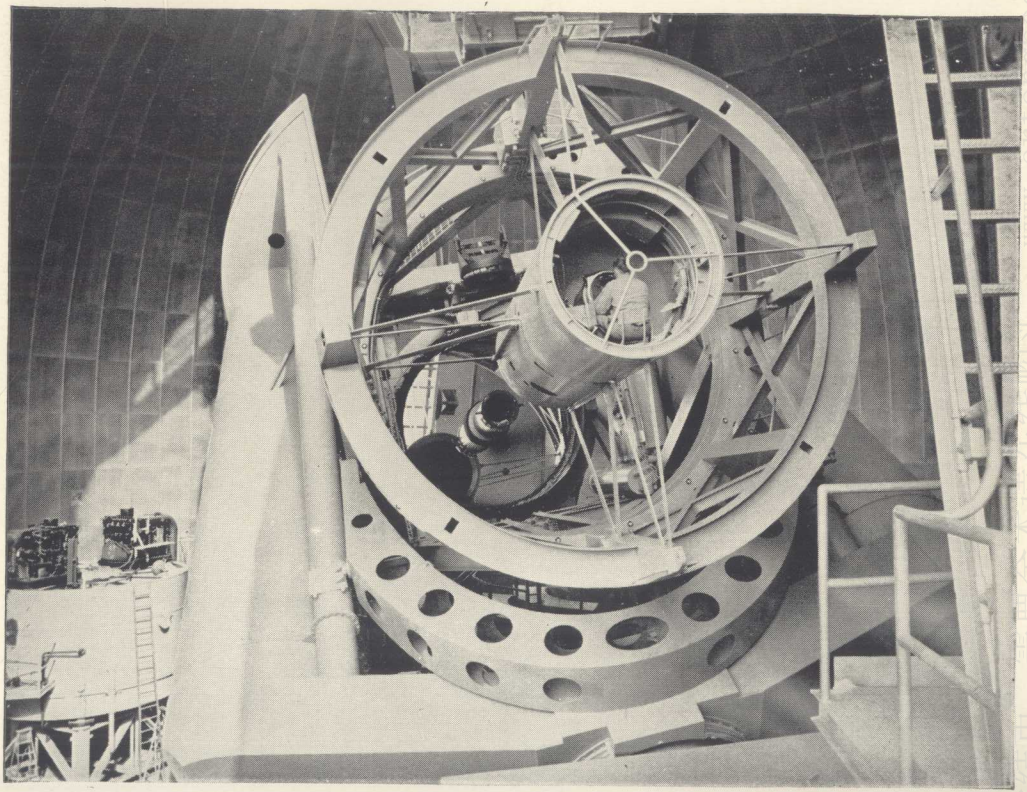


IV. A large group of sunspots photographed on 17 May 1951. Solar flares often erupt in the vicinity of developing sunspots and are associated with powerful radio emission. (*By courtesy of the Mount Wilson and Palomar Observatories.*)



V. The relation between red-shift and distance for extragalactic nebulae. Red-shifts are expressed as apparent velocities of recession, $c\,d\lambda/\lambda$. Arrows indicate the shift of the calcium lines H and K. One light-year is approximately 6 million million miles or 6×10^{12} miles.

(*By courtesy of the Mount Wilson and Palomar Observatories.*)



VI. The 200-inch Hale telescope on Mount Palomar showing the observer in the prime focus cage and the reflecting surface of the 200-inch mirror. (*By courtesy of the Mount Wilson and Palomar Observatories.*)

VII. The Great Spiral Nebula in Andromeda (M31) photographed with the 48-inch Schmidt camera on Mount Palomar. The galaxy is 2 million light years distant and is just visible to the naked eye if conditions are good. The nebula probably contains 100,000 million stars and is believed to be similar to the Milky Way system. (*By courtesy of the Mount Wilson and Palomar Observatories.*)

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THE NATURE OF THE UNIVERSE

MAN'S view of the universe has been enormously expanded during the years since the close of the second world war, primarily because of the new techniques of radio astronomy and the space probe. It was, however, the introduction of the great optical telescopes which led to the major revolution in our ideas about the size and organization of the cosmos. Until about forty years ago we still believed that the system of stars visible in the sky on any clear night, and known as the Milky Way, was confined in space and itself represented the totality of the universe. Even so short a time ago we believed that the Sun, the Earth, and the attendant planets were situated at the centre of this system of stars, and that the Sun was a typical star and seemed bright because it was close to us. The stars appeared faint, not because they were small and insignificant, but because they were at great distances. Nevertheless we believed that we were privileged to be situated in the centre of this assembly. It was estimated that there were many thousands of millions of stars in this Milky Way system and they were believed to be distributed in an approximately spherical enclosure of a size such that it would take a ray of light travelling 186,000 miles a second a few thousand years to traverse it. These ideas have been changed completely.

The investigations which were carried out by the American astronomers in the few years after 1920 following the opening of the 100-inch telescope on Mount Wilson showed that this egocentric view was wrong; that, in fact, the stars of the Milky Way were arranged in a disc of extent such that a ray of light would take a hundred thousand years to traverse the distance separating the extremities of the stars, and that the system was

asymmetrical. If one could remove oneself from the Milky Way system and look back on it through a large telescope then the stars would appear to be arranged in a flattened disc with the stars concentrated in spirals radiating from the central hub like a giant octopus. It was realized too that the Sun, far from being at the centre of this disc of stars, was situated in an unfavourable position somewhere near the edge of the disc.

We know that this Milky Way system or local galaxy contains about one hundred thousand million stars. The Earth is a planet of the Sun's family, 93 million miles away. The most distant planet in our solar system, Pluto, is a few thousand million miles distant, so far away that the light from the Sun takes about $6\frac{1}{2}$ hours on its journey towards the planet Pluto. These distances, which are still just conceivable in terrestrial terms, are minute compared with the distance which separates our solar family from the nearest star in space. In order to describe these distances it is convenient to use the expression known as the 'light year', which is the distance which a ray of light travels during the course of a year. The speed of light is 186,000 miles per second; the light from the Sun takes 8 minutes on its journey, therefore the Sun is at a distance of 8 light minutes. The light from Pluto takes $6\frac{1}{2}$ hours on its journey to Earth so Pluto is $6\frac{1}{2}$ light hours away. On the other hand the nearest star is enormously more distant, so far away that the light from it takes $4\frac{1}{2}$ years on its journey.

It is important to realize that our knowledge in astronomy is almost entirely of time past. We have no knowledge whatsoever of time present. Our knowledge of the Sun is 8 minutes old, our knowledge of the nearest star is $4\frac{1}{2}$ years out of date, and our knowledge of some of the stars which we see in the Milky Way may be a hundred thousand years out of date because the light from these stars has taken a hundred thousand years on its journey through space towards us. The presence in the sky of faint nebulous patches had been known for a long time and, in fact, Herschel speculated in the nineteenth century that these nebulae might be other systems of stars outside our Milky Way system; but it was not until the 100-inch telescope on Mount