

# A HISTORY OF ASTRONOMY

A. PANNEKOEK

"... a carefully reasoned history of astronomy ... clearly the work of a man who loved his subject."—*The Times* (London) *Literary Supplement*

Few histories of astronomy offer the special human dimension of this book. For the late Professor Pannekoek (University of Amsterdam), the history of astronomy consisted in the growth of man's concept of his world. The study of the cosmos became an essential part of the history of human culture, an adventure of the mind.

In this well-balanced account of that adventure, the author is at pains to relate the development of astronomy to the social and cultural background in which it is nurtured. Thus, the effect of changes in political conditions, the influence of geography, the growth of industry and of communications methods are clearly and incisively described.

Dr. Pannekoek begins with an unusually detailed account of astronomy in ancient times, including Babylonian sky-lore, Assyrian astrology, the Ptolemaic world-view, Hellenistic astronomy, the epicycle theory, and Arabian astronomy. The growth of astronomy after Copernicus comprises the second part of the book, acquainting the reader with the epoch-making work of Kepler and Newton and the astonishing developments of celestial mechanics during the eighteenth century. Part III begins with Herschel, the gifted amateur whose observations opened up new horizons, and ends with Eddington's pioneering studies of the internal constitution of stars.

Comprehensive, well-written and full of small, revealing details that attest to the scope and depth of the author's learning, this splendid survey belongs in the library of every astronomer—or anyone interested in the grand mystery of the cosmos and man's attempts to penetrate it.

Unabridged, unaltered Dover (1989) republication of the edition published by Allen & Unwin, 1961. (Originally published in Dutch by Wereld-Bibliotheek, Amsterdam, 1951.) Introduction. References. Appendices. 42 figures. 24 black-and-white photographs. 521pp. 5% × 8%. Paperbound.

## ALSO AVAILABLE

- A HISTORY OF ASTRONOMY FROM THALES TO KEPLER, J. L. E. Dreyer. 438pp. 5% × 8%. 60079-3 Pa. \$9.95
- THE HISTORY OF THE TELESCOPE, Henry C. King. 480pp. 6% × 9%. 23893-8 Pa. \$12.95
- A SHORT HISTORY OF ASTRONOMY, Arthur Berry. 440pp. 5% × 8%. 20210-0 Pa. \$10.95

ISBN 0-486-65994-1



PUBLISHERS PRICE  
NON NETT  
£12.95  
IN USA

Cover Design by Edmund V. Gillon, Jr.

# A HISTORY OF ASTRONOMY

DOVER 0-486-65994-1



PANNEKOEK



A. PANNEKOEK

# A HISTORY OF ASTRONOMY





## DOVER BOOKS ON ASTRONOMY

- THE ASTRONOMICAL REVOLUTION, Alexandre Koyre. (Available in United States only). (27095-5) \$11.95
- KEPLER, Max Caspar. (67605-6) \$10.95
- A HISTORY OF ASTRONOMY, A. Pannekoek. (65994-1) \$12.95
- ELLIPSOIDAL FIGURES OF EQUILIBRIUM, S. Chandrasekhar. (65258-0) \$8.95
- EXPLORING THE MOON THROUGH BINOCULARS AND SMALL TELESCOPES, Ernest H. Cherrington, Jr. (24491-1) \$14.95
- AN INTRODUCTION TO CELESTIAL MECHANICS, Forest Ray Moulton. (64687-4) \$12.95
- WONDERS OF THE SKY: OBSERVING RAINBOWS, COMETS, ECLIPSES, THE STARS AND OTHER PHENOMENA, Fred Schaaf. (24402-4) \$8.95
- STAR NAMES: THEIR LORE AND MEANING, Richard H. Allen. (21079-0) \$9.95
- STRUCTURE AND EVOLUTION OF THE STARS, Martin Schwarzschild. (61479-4) \$8.95
- PLANETS, STARS AND GALAXIES, A.E. Fanning. (21680-2) \$6.95
- BURNHAM'S CELESTIAL HANDBOOK, Robert Burnham Jr. (23567-X, 23568-8, 23673-0) Three-volume set \$41.85
- ARISTARCHUS OF SAMOS, Sir Thomas L. Heath. (24188-2) \$10.95
- GREEK ASTRONOMY, Sir Thomas L. Heath. (26620-6) \$6.95
- AN INTRODUCTION TO THE STUDY OF STELLAR STRUCTURE, S. Chandrasekhar. (60413-6) \$11.95
- RADIATIVE TRANSFER, S. Chandrasekhar. (60590-6) \$11.95
- A HISTORY OF ASTRONOMY FROM THALES TO KEPLER, John L.E. Dreyer. (60079-3) \$10.95
- THE FRIENDLY STARS, Martha E. Martin. (21099-5) \$3.95
- COMETS: SPECULATION AND DISCOVERY, Nigel Calder. (27879-4) \$8.95
- AMATEUR ASTRONOMER'S HANDBOOK, J.B. Sidgwick. (Available in United States only). (24034-7) \$9.95
- OBSERVATIONAL ASTRONOMY FOR AMATEURS, J.B. Sidgwick. (Available in United States only). (24033-9) \$8.95

THE HISTORY OF ASTRONOMY

BY A. PANNEKOEK

TRANSLATED BY

W. F. D. W. ...

...

...

...

...

...

...

...

...

...

...

A. PANNEKOEK

# A HISTORY OF ASTRONOMY

ILLUSTRATED

DOVER PUBLICATIONS, INC.

NEW YORK

A HISTORY OF  
ASTRONOMY

A. PANNEKOEK

# A HISTORY OF ASTRONOMY

ILLUSTRATED

DOVER PUBLICATIONS, INC.  
NEW YORK



# A HISTORY OF ASTRONOMY

Copyright © 1961 by George Allen and Unwin Ltd.  
All rights reserved under Pan American and International  
Copyright Conventions.

Published in Canada by General Publishing Company, Ltd., 30  
Lesmill Road, Don Mills, Toronto, Ontario.

Published in the United Kingdom by Constable and Company,  
Ltd.

This Dover edition, first published in 1989, is an unabridged  
and unaltered republication of the work first published by George  
Allen & Unwin Ltd., London, in 1961. It is reprinted by special  
arrangement with Unwin Hyman Ltd., 15-17 Broadwick Street,  
London W1V 1FP. The original Dutch edition, *De Groei van ons  
Wereldbeeld*, was first published in 1951 by Wereld-Bibliotheek,  
Amsterdam.

Manufactured in the United States of America  
Dover Publications, Inc., 31 East 2nd Street, Mineola, N.Y.  
11501.

## Library of Congress Cataloging-in-Publication Data

Pannekoek, Anton, 1873-1960.

[Groeï van ons wereldbeeld. English]

A history of astronomy / A. Pannekoek.

p. cm.

Translation of: *De groei van ons wereldbeeld*.

Bibliography: p.

Includes index.

ISBN 0-486-65994-1

1. Astronomy—History. I. Title.

QB15P28313 1989

520'.9—dc20

89-7794  
CIP

## CONTENTS

INTRODUCTION	page 13
PART ONE: ASTRONOMY IN THE ANCIENT WORLD	
1. Life and the Stars	19
2. Agriculture and the Calendar	23
3. Old Babylonian Sky-Lore	28
4. Assyrian Astrology	36
5. New-Babylonian Science	48
6. Chaldean Tables	63
7. Egypt	82
8. China	86
9. Greek Poets and Philosophers	95
10. Calendar and Geometry	106
11. Systems of World Structure	113
12. Hellenistic Astronomy	122
13. The Epicycle Theory	133
14. The Close of Antiquity	145
15. Arabian Astronomy	164
PART TWO: ASTRONOMY IN REVOLUTION	
16. Dark Europe	173
17. The Renaissance of Science	178
18. Copernicus	188
19. Astronomical Computing	199
20. Tycho Brahe	204
21. The Reform of the Calendar	217
22. The Struggle over the World System	222
23. Kepler	235
24. Mechanics and Philosophy	245
25. The Telescope	253
26. Newton	261
27. Practical Astronomy	276
28. Astronomers on the Move	282
29. Refined Practice	289
30. Refined Theory	297



CONTENTS

PART THREE: ASTRONOMY SURVEYING  
THE UNIVERSE

31. The World Widens	311
32. The Technical Basis	321
33. Distances and Dimensions	339
34. Celestial Mechanics	351
35. Plurality of Worlds	371
36. Cosmogony and Evolution	394
37. The Sun	403
38. Passing Luminaries	419
39. Peculiar Stars	429
40. Common Stars	444
41. The Galactic System	467
42. Into Endless Space	483
43. The Life of the Stars	491
APPENDICES	497
REFERENCES	502
INDEX	507

ILLUSTRATIONS

1. The Assyrian Tablet, K725	<i>facing page</i> 160
Chinese Star Map	
2. The Constellations on the Farnese Atlas	161
3. Copernicus	192
Tycho Brahe	
4. Galileo	193
Two drawings of the moon by Galileo	
5. Johannes Kepler	256
Christiaan Huygens	
6. Picard's Zenithsector	257
Huygens' tubeless telescope	
Hevelius and his Quadrant	
Hevelius' map of the full moon	
7. Isaac Newton	288
James Bradley	
8. <i>Top left:</i> Römer's meridian instrument	289
<i>Right:</i> Bird's Quadrant	
<i>Left:</i> The Paris Observatory	
9. <i>Top Left:</i> William Herschel	320
<i>Right:</i> Herschel's 20-foot telescope	
<i>Left:</i> Herschel's section of the Milky Way	
10. <i>Left:</i> Reichenbach's meridian circle	321
<i>Right:</i> Friedrich Wilhelm Bessel	
11. The Hyginus Crater and its surroundings	352
12. Drawings of Mars	353
13. Sections of the solar spectrum	384
14. Donati's Comet, 1858	385
Donati's Comet, enlarged	
Morehouse's Comet	
15. Part of Orion, extrafocal exposure	416
Doubling of the K line in $\beta$ Auriga	
Spectra by W. Huggins	
16. Constellation of Orion by Argelander	416-417
Constellation of Orion by Bayer	
17. Huggins' first ultra-violet stellar spectra	416-417
Types of star spectra according to A. Secchi	



ILLUSTRATIONS

18. Harvard types of stellar spectra	<i>facing page</i> 417
19. Sir Arthur Eddington	448
20. Telescopic stars in the Belt of Orion	448-449
21. Milky Way; Cygnus	448-449
22. The Andromeda Nebula	449
23. Radial speeds of nebulae	480
24. The Jodrell Bank Radio Telescope	481

INTRODUCTION

ASTRONOMICAL science originated in a much earlier period of human history than the other natural sciences. In the remote past, when practical knowledge in daily life and work had not yet led to a systematic study of physics and chemistry, astronomy was already a highly-developed science. This antiquity determines the special place which astronomy has occupied in the history of human culture. The other realms of knowledge developed into sciences only in later centuries and this development took place mainly within the walls of universities and laboratories, where the noise of political and social strife seldom penetrated. Astronomy, on the contrary, had already manifested itself in the ancient world as a system of theoretical knowledge that enabled man to prophesy even the terrifying eclipses and had become a factor in his spiritual strife.

This history is associated with the process of the growth of mankind since the rise of civilization and, to a great extent, belongs to times in which society and the individual, labour and rite, science and religion, still formed undivided entities. In the ancient world and in the following centuries astronomical doctrine was an essential element in the world concepts, at once religious and philosophical, which reflected social life. When the modern physicist looks back at his earliest predecessors, he finds men like himself, with similar though more primitive views on experiment and conclusion, on cause and effect. When the astronomer looks back at his predecessors, he finds Babylonian priests and magicians, Greek philosophers, Mohammedan princes, medieval monks, Renaissance nobles and clerics—until in the scholars of the seventeenth century he meets with modern citizens of his own kind. To all these men astronomy was not a limited branch of specialist science but a world system interwoven with the whole of their concept of life. Not the traditional tasks of a professional guild but the deepest problems of humanity inspired their work.

The history of astronomy is the growth of man's concept of his world. He always instinctively felt that the heavens above were the source and essence of his life in a deeper sense than the earth beneath. Light and warmth came from heaven. There the sun and the other celestial luminaries described their orbits; there dwelt the gods who ruled over his destiny and wrote their messages in the stars. The heavens were near and the stars played their part in the life of man. The study of the stars was the unfolding of this higher world, the noblest object that human thinking and spiritual effort could find.

This study, continued through many centuries, and even in antiquity,



taught two things: the periodic recurrence of celestial phenomena and the vastness of the universe. Within the all-encompassing celestial sphere with its stars, the earth, though for man the centre and chief object, was only a small dark globe. Other world bodies—sun, moon and planets, some of them of larger size—circulated around her. This was the world concept which, when the ancient world collapsed and science fell into a depression lasting a thousand years, was kept as a heritage and at the end of the Middle Ages was transmitted to the rising West-European culture.

There, in the sixteenth century, driven by a strong social development, astronomy gave rise to a new concept of the world. It disclosed that what seemed the most certain knowledge of the foundation of our life—the immobility of the earth—was merely an appearance. It showed moreover, that our earth was only one of several similar planets, all revolving about the sun. Beyond was endless space with the stars as other suns. It was a revolution, opening new ways of thinking. With hard effort and much strife mankind had to reorientate itself in its world. In those centuries of revolution the contest over astronomical truth was an important element in the spiritual struggle accompanying the great social upheavals.

Astronomy, like the study of nature in general, now entered a new era. The next century brought the discovery of the fundamental law controlling all motions in the universe. Philosophical thinking was for the first time confronted with an exact and strict law of nature. The old mystical, astrological connection between the heavenly bodies and man was replaced by the all-pervading mechanical action of gravitation.

Then, at last, in the modern age of science, the concept of the universe widened to ever larger dimensions, expressible only in numbers, against which to speak of the smallness of the earth is a meaningless phrase. Again—or still—astronomy is the science of the totality of the universe, though now merely in a spatial sense. Whereas in the ancient world the idea of the unity of the heavenly and the human worlds exalted the hearts of the students of nature, now men are stirred by the proud consciousness of the power of the human mind, which from our small dwelling place is able to reach up to the remotest stellar systems.

In early times, when physical theory was but abstract speculation, astronomy was already an ordered system of knowledge giving practical orientation in time and space. In later centuries, astronomical research was directed more and more towards theoretical knowledge of the structure of the universe, far beyond any practical application, to satisfy the craving for truth, i.e. for intellectual beauty. Then the mutual relation of the sciences became the opposite of what it had been before. Physics, chemistry, and biology shot up with increasing rapidity.

Through technical applications they revolutionized society and changed the aspect of the earth. In this revolution astronomy stood aside. The stars cannot contribute to our techniques, our material life, or our economic organization. So their study became more and more an idealistic pursuit tending toward a physical knowledge of the universe. While the other sciences won brilliant triumphs in a transformation of the human world, the study of astronomy became a work of culture, an adventure of the mind. Its history thus remains what it has always been, an essential part in the history of human culture.

Whoever penetrates into the past participates in the development of the human race as his own experience. It is the aim of this work to unfold in this past the development of our astronomical world concept as a manifestation of humanity's growth.