A NEW ASTRONOMY

BY

DAVID TODD

M.A., PH.D., F.R.S.A.

Professor Emeritus of Astronomy and Former Director of the Observatory
Amherst College

"hypotheses non fingo"
Is. Newton

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— '*Contemplated as one grand whole, astronomy is the most beautiful monument of the human mind, the noblest record of its intelligence.*' — LA PLACE

— '*The attempt to convey scientific conceptions, without the appeal to observation, which can alone give such conceptions firmness and reality, appears to me to be in direct antagonism to the fundamental principles of scientific education.*' — HUXLEY

To

D. W. I. and A. C. I.

in grateful memory

of 'Coronet' days

W. P. 22

MADE IN U.S.A.

PREFACE

NEGLECT hitherto of the availability of astronomy for a laboratory course has mainly led to the preparation of this *New Astronomy*. Written purely with a pedagogic purpose, insistence upon rightness of principles, no matter how simple, has everywhere been preferred to display of precision in result. To instance a single example: although the pupil's equipment be but a yardstick, a pinhole, and the 'rule of three,' will he not reap greater benefit from measuring the sun for himself (page 259), than from learning mere detail of methods employed by astronomers in accurately measuring that luminary?

Astronomy is preëminently a science of observation, and there is no sufficient reason why it should not be so studied. Thereby will be fostered a habit of intellectual alertness which lets nothing slip. Sixteen years' experience in teaching the subject has taught me many lessons that I have endeavored to embody here. Earth, air, and water (merely material things) are always with us. We touch them, handle them, ascertain their properties, and experiment upon their relations. Plainly, in their study, laboratory courses are possible. So, too, is a laboratory course in astronomy, without actually journeying to the heavenly bodies; for light comes from them in decipherable messages, and geometric truth provides the interpretation. But the student should learn to connect fundamental principles of astronomy with tangible objects of the common sort, somewhat as in physics and chemistry; and I have aimed to indicate practically how teachers and pupils of moderate mechanical deftness can themselves make the apparatus requisite for illustrating many of these principles. All of it has been repeatedly constructed; and its use should pave the way to better equipment for more advanced study.

Especial attention has been accorded the recommendations of 'The Committee of Ten' on secondary school studies (1892); the specifications concerning astronomical instruction published by the Board of Regents of the state of New York (1895); and the Action of the

Editorial Board of *The Astrophysical Journal* with regard to Standards in Astrophysics and Spectroscopy (1896).

In order to secure the fullest educational value, I have aimed to present astronomy, not as mere sequence of isolated and imperfectly connected facts, but as an inter-related series of philosophic principles. The geometrical concept of the celestial sphere is strongly emphasized; also its relation to astronomical instruments. But even more important than geometry is the philosophical correlation of geometric systems. Ocean voyages being no longer uncommon, I have given rudimental principles of navigation in which astronomy is concerned. Few young students may ever see the inside of an observatory; but that is reason for their knowing about the instruments there, and prizing opportunities to visit such institutions.

Everywhere has been kept in mind the importance of the student's thinking rather than memorizing. Mere memorizing should be rendered facile; in treating of the planets, I have therefore presented our knowledge of those bodies, not subdivided according to the planets themselves as usually, but according to especial elements and features. The law of universal gravitation has received fuller exposition than commonly in elementary books, its significance demanding this. Biographic notes, intrusions in the text, have been relegated to the Index.

In conclusion, I desire to thank Professor Newcomb of Washington, Professor Pickering, Director of Harvard College Observatory, and my colleague, Professor Kimball, for helpful suggestions on the proof sheets. A few illustrations have been reëngraved from the *Lehrbuch der Kosmischen Physik* of Müller and Peters. For many of the excellent photographs, reader, publisher, and author are indebted to the courtesy of astronomers, in particular to M. Tisserand, late Director of the Paris Observatory, to the Astronomer Royal, to Professor Pickering, to Professor Hale; also to Dr. Isaac Roberts and Professor Barnard, both of whose series of astronomical photographs have received the highly honorable award of the gold medal of the Royal Astronomical Society.

DAVID TODD

AMHERST COLLEGE OBSERVATORY.

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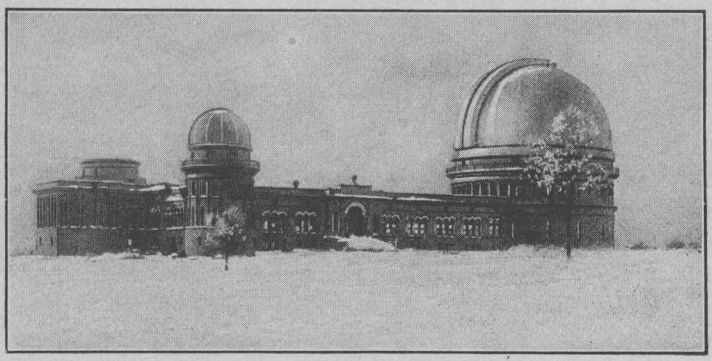
NEW ASTRONOMY

CHAPTER I

INTRODUCTORY

ASTRONOMY is the science pertaining to all the bodies of the heavens. Parent of the sciences, it is the most perfect and beautiful of all. Sir William Rowan Hamilton, the eminent mathematician, has called astronomy man's golden chain between the earth and the



The Yerkes Observatory, Professor Edwin B. Frost, Director

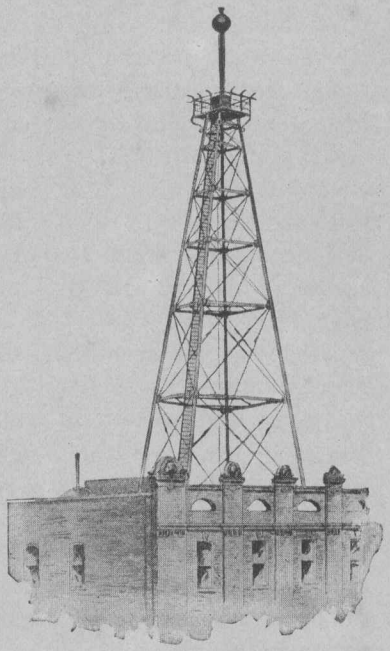
visible heaven, by which we 'learn the language and interpret the oracles of the universe.' This noble science is to man a possession both old and ancestral, passing with resistless progress from simple shepherds of the Orient watching their flocks by night, to the rulers of ancient

empires and the giants of modern thought; until to-day the civilized world is dotted with observatories equipped with a great variety of instruments for weighing and measuring and studying the celestial bodies, each of these observatories vying with the others in pure enthusiasm for new knowledge of the infinite spaces around us.

Astronomy a Useful Science. — Many devoted lives have been grandly spent in pursuit of this branch of learning; and it would hardly be possible for any one who has given even a general glance at their unselfish history to make the vulgar inquiry, 'What's the use?' Only a very small and unaspiring mind ever asks this question about any science which adds to the sum total of our actual knowledge, least of all with reference to this, — one of the most practical of all sciences. Astronomy binds earth and heaven in so close a bond that it even maps the one by means of the other, and guides fleet and caravan over wastes of sea and sand otherwise trackless and impassable. By faithful study, even for a short time, it is possible to discover many of these uses. They may not at once appear to put money into men's pockets or clothes upon their backs; but we have passed the primitive stage of a rudely toiling community, where material progress alone is the thought and aim.

Especial Uses. — To specify in part the relations in which astronomy is useful: (1) In *chronology*, — fixing many disputed dates of ancient battles, the reigns of kings, and other important historic events, and establishing the exact length of the units of time requisite for the calendar. For example, the surest basis of the chronology of ancient Assyria rests upon an eclipse of the sun observed in Nineveh in the middle of the reign of Jeroboam the Second, which modern astronomical calculations prove to have taken place on the 15th of June, B.C. 763. (2) In *navi-*

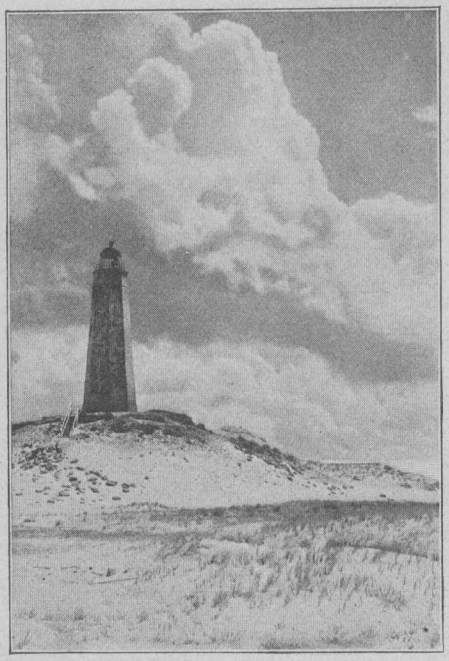
gation, — conducting ships from port to port, almost without risk, thereby saving human life and lessening the cost of many of the necessaries of existence. The great national observatory at Greenwich (page 433) is one of those founded for the especial and practical purpose of improving the astronomical means of navigation. (3) In *geodesy* and in *surveying*, — enabling us to ascertain the size of the earth, make accurate maps of its continents and oceans, and run boundaries of countries and estates. (4) In determining exact *time*, — a vast convenience in all the affairs of life, particularly in the operation of railways. Every good clock and watch has been carefully rated by comparison, either direct or indirect, with an accurate clock (perhaps in some astronomical observatory), which again has been corrected by observations of the fixed stars — a knowledge of the precise positions of which depends upon the faithful patience of a multitude of astronomers who have given their lives to this work in the past. Indeed, it is hardly an exaggeration to say that there is no civilized person in existence whose comfort is not enhanced, whose life is not rendered more worth the



An Old Way of Marking Exact Time was by Dropping a Time Ball Every Noon from Some High Tower

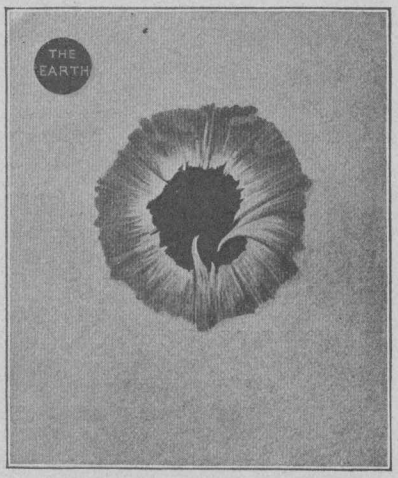
living, or who is not affected, at least indirectly, by the work of astronomers, and by those who, though not astronomers, are yet practically applying the principles of this science to the affairs of everyday life.

The Sun by Day. — Singularly few persons regard the daytime sky. Yet this beautiful and ever-varying spectacle may be seen and enjoyed by all; perhaps that is one reason why it is so little thought of. Even the sordid city court, the worst tenement district, may have its strip of blue above, far away from noise and uncleanliness. No buildings are high enough to shut out this heavenly gift entirely. The study of the sky in daylight, especially its clouds, is properly part of a separate science, — meteorology as distinguished from astronomy. The marvelous sun, too, by which, as will be seen, we live and move and have our being, is held hardly less a matter of course. Here it is that meteorology joins on the boundary of the science we take up to-day; for the sun is one of the chief objects of study in modern astronomy, — its distance, its



Clouds of the Daytime Sky (photographed by Henry)

vast size, its apparent motion, the sources of its intense light and heat, its constantly changing spots, its constitution, the hydrogen prominences, which seem to spring from its edge as tongue-like flames, and its energies, tirelessly radiated into space and regnant in all the forms of life upon the earth, no less than in all those phenomena of the atmosphere which we call weather. Many of the spots on the sun are larger than our globe, like the one here pictured. Without fine instruments carefully adjusted, the prominences cannot be seen except during total eclipses of the sun.



An Average Sunspot (Moreux)

The Stars by Night. — But this sense of everyday usualness in great part gives way, once the sun has set, and the stars have come forth, as if from their daytime hiding. Of course they fill the sky just as truly when the world is flooded with sunlight, shining all in their appointed places, where the brighter ones may be seen with the telescope during the day; but their feebler light is conspicuous only when this greater brilliance is withdrawn from our horizon, or when the moon comes in between us and the sun, causing a total eclipse. Immanuel Kant, a great German philosopher, has said that two things filled him with ceaseless awe, — the starry heavens above and the moral law within. Even the most prosaic cannot but notice and revere the night-time sky, and few are so

hopelessly unimaginative as not to be impressed by the dark blue dome spangled with its myriad stars. The positions of the stars with reference to one another seem to remain constant, although they are continually changing their places relatively to objects on the earth. Hence the term *fixed stars*. But this is only seemingly the proper expression. In reality, all are speeding through space at

The Night-time Sky in a Great City

very high velocities, but so infinitely removed are the stars from us that they appear to be at rest. Although quite the reverse, as we now know, from 'fixed,' the term is still used, because in the astronomically brief period from generation to generation, the changes are so slight that the naked eye is powerless to detect them.

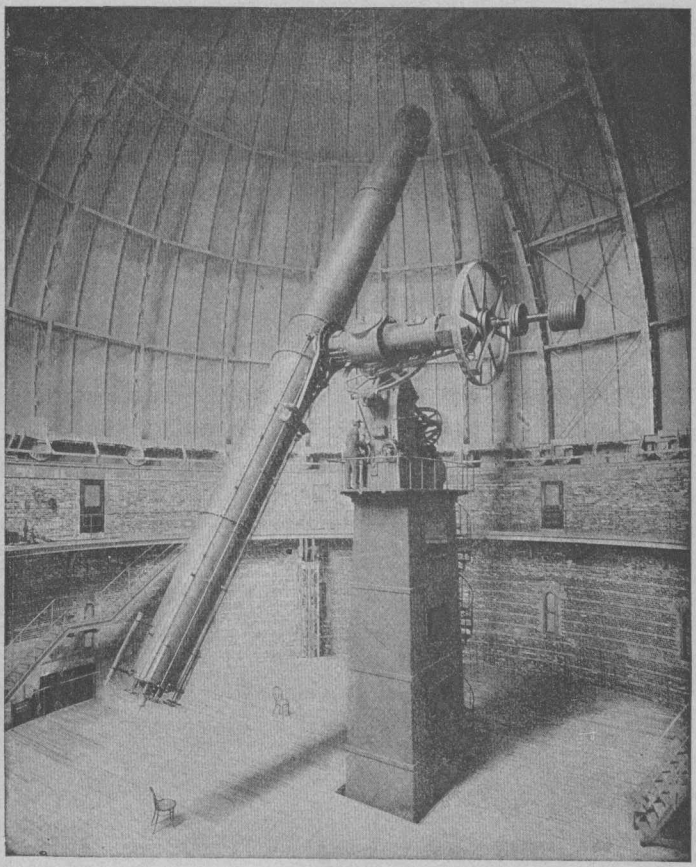
Number of the Brighter Stars. — In ancient times the brilliant host of the nightly sky was thought to be countless; but surprising as it may seem, the stars actually visible to the unaided eye at a single place in the United States do not exceed 2000 or 3000, and only upon ex-

The Milky Way near the Star 15 Monocerotis, Æ R = 6 h. 35 m., Decl. N. 10°
(photographed by Barnard, 1894. Exposure 3½ hours)

ceptionally favorable nights may so many be counted without a telescope. As an average, on what may be termed clear nights, the number thus ordinarily seen at any given time is rather less than 2000; but this number varies greatly with changing conditions of our atmosphere. If one were to keep count, through the year, of all the stars visible to the naked eye in all that part of the heavens ever seen from a single place in the United States, the total number would be about 4000.

Number of the Telescopic Stars. — By the use of a small telescope, or even an opera glass, the number of visible stars is increased enormously. Even in Galileo's time, his 'optick tube' revealed an unsuspected and unnumbered host, beyond the dreams of any primitive astronomer. With our modern telescopes (in which the object glass of almost every famous new one has been an advance in size upon all its predecessors) the 'blue field of heaven' is estimated to contain at least 100,000,000 stars. Beyond what is shown even by these telescopes are the remarkable revelations of celestial photography, which reproduces unerringly upon the sensitive plate uncounted millions of other stars too faint for the eye to detect, even when aided by the most powerful optical means at our command. In a single field embracing but a slight fraction of the whole sky, recently charted with the Bruce telescope of Harvard Observatory (the largest photographic instrument in existence), there were counted no less than 400,000 stars. And who can say where this stupendous array ceases?

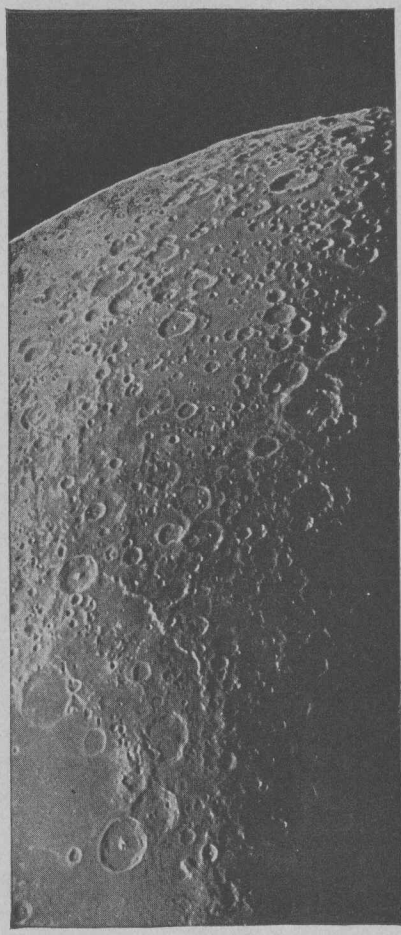
The Constellations. — The names and positions of the brighter stars are very easy to remember. By even a casual glance at the sky on any clear night, it will be seen that the stars make all sorts of figures with one another, — squares, triangles, half circles, — and fanciful combinations may be traced in all directions. The ancients called these



The Yerkes Telescope of the University of Chicago

This great telescope was mounted in 1896–97 at Williams Bay, Wisconsin. It is the principal instrument of the Yerkes Observatory, and cost about $125,000. The glasses for its 40-inch lenses, **the largest in America, were** made by M. Mantois of Paris, ground and figured by Alvan Clark & Sons of Cambridgeport; and the tube and all the intricate machinery for handling the telescope with ease and precision were built by Warner & Swasey of Cleveland.

various figures after their gods and heroes, dividing them into 48 groups, largely named after the characters associated with the voyage of the fabled ship *Argo*. Although these constellations bear little real resemblance to the men, animals, and other objects named, they too are easily learned. Properly that is not astronomy, but merely geography of the heavens; yet it is an interesting and popular branch of knowledge, often leading to farther studies into the most absorbing and uplifting of sciences.



The Moon (photographed by the Brothers Henry)

The Moon. — Of all celestial bodies, meteors alone excepted, the moon is the nearest to us, and apparently of about the same size as the sun; but this is the result of a somewhat curious coincidence, by which the sun, although 400 times broader than the moon, is also very nearly 400 times farther away. Even with a small telescope we may generally see the deep craters and the rugged mountain peaks of the moon, partly