THE FUNDAMENTALS OF ASTRONOMY

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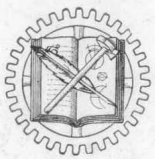

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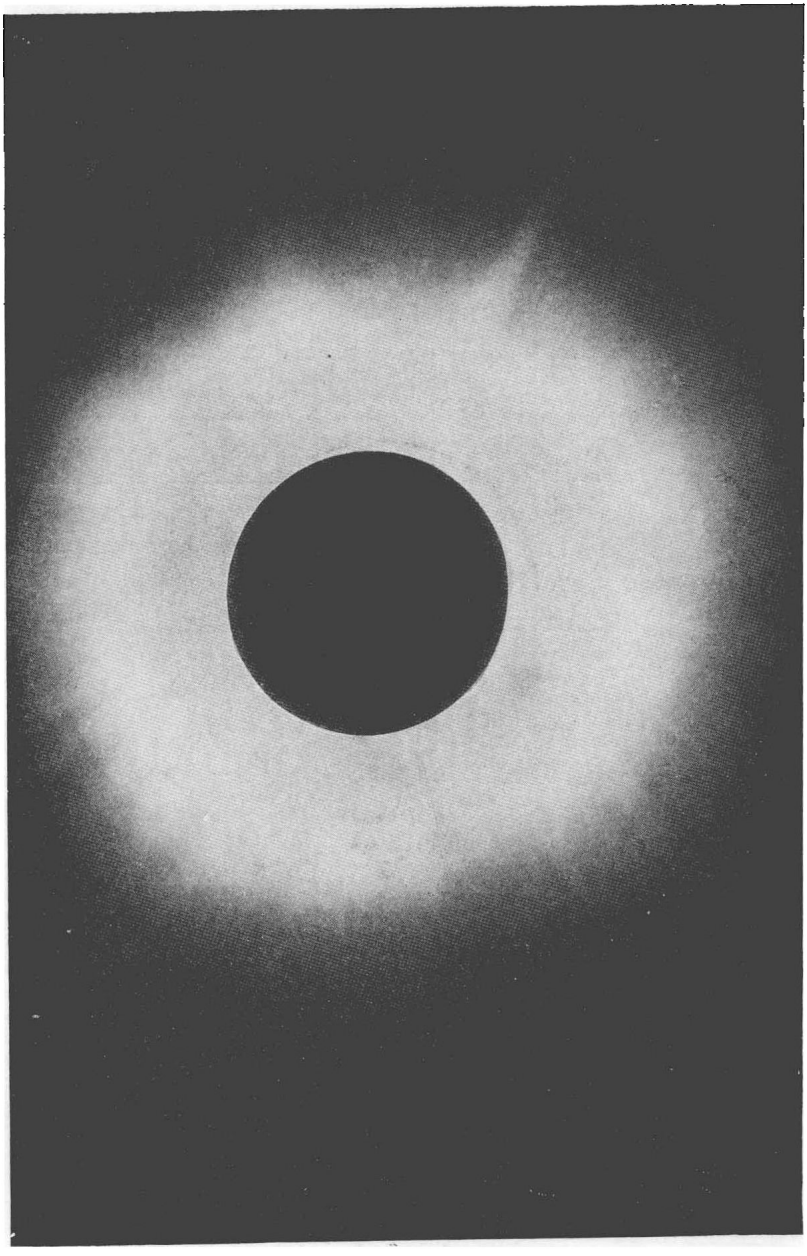

THE TOTAL ECLIPSE OF 1926.

PREFACE

It is unquestionable that a knowledge of astronomy is of great cultural value. No science has done more to broaden the outlook and uplift the mind above superstition and bigotry, nor has any science contributed more to the satisfactions of a wide mental horizon.

If this book will assist to enlarge the circle of those who elect astronomy as a general study and thus will multiply the number of people who appreciate the wonders of the universe, it will have fulfilled its purpose.

This textbook, though based on " The Earth and the Stars," which was published recently by one of the present authors, has been so modified, corrected, modernized and amplified, that it is practically a new work. However, the authors have attempted to retain the non-technical character of the original and to relieve the tedium of the ordinary textbook by anecdotes and historical allusions and thus to stimulate the interest of the student.

It is felt that the book is suitable for elementary courses as given in the average university and college. Those details of practical astronomy which the student ought to know are a part of the book and no little astrophysical data is included. The fact that each of the authors has had a wide experience in modern astronomical research as a director of an observatory should tend to interest the student by close association with original sources.

The charts of the constellations are copyrighted and are printed through the kind permission of the Eastern Science Supply Company.

S. A. Mitchell
C. G. Abbot

May 15, 1927.

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FUNDAMENTALS OF ASTRONOMY

CHAPTER I

HOW TO KNOW THE STARS

In order to know and love "the silence that is in the starry skies," one should follow the advice of the famous American astronomer, the late Professor Simon Newcomb, who recommended everyone to go alone on a clear, sparkling, moonless night to a hill in the country where there is a wide horizon. Let us suppose that we follow his advice in the month of October and watch the slow majestic march of the stars as one by one they rise, cross the sky, and set. Soon after sunset, we take our place to watch the sky unaided by other instruments than our eyes, like the Magi who followed the star of Bethlehem.

Let us look first towards the western sky, before its stars are set. The twilight still shows a dusky sunset glow far down next the horizon. In October of each of the years 1925 to 1929, and in the sixth year after each of these, the little planet Mercury, our sun's nearest neighbor, is evening star, and on clear nights can be seen for a half hour or more after sunset, very near the spot on the western horizon where the sun went down. Similarly in October of the years 1928, 1930, 1931, 1933, and on the eighth year after each of these, the planet Venus, our nearest neighbor after the moon, is evening star. Being farther from the sun than Mercury, she often reaches a much higher standing in the western sky after sunset, and may sometimes be followed for three hours before she sets. Venus, albeit not equally brilliant in each of the above years, is the brightest of all the heavenly bodies except the sun and moon.

Every October in the years 1923 to 1927, the great planet Jupiter is visible in the evening hours, and in the years 1923 to 1933 Saturn also. If we had a telescope we should see the wonderful rings of Saturn, perhaps the most beautiful of all celestial sights. Mars, the fiery red planet, is evening star in October of the years 1929, 1931, and every second year thereafter till 1939. All of these

five bright planets, and Uranus and Neptune also, which can not be distinguished without a telescope because they are far away and faint, follow nearly the path of the sun, and are therefore never far away from the plane of the ecliptic. Although we loosely speak of them as morning or evening stars, the planets are not stars at all. They belong to the family of our sun, and shine by reflecting his light. Stars, on the contrary, are other suns, immensely distant and shine by their own light. Planets appear to wander about among the stars. Stars retain their relative places with slight change from year to year.

It makes a great difference in the face of the starry sky how far to the north or the south one lives. The Southern Cross, for instance, is never visible north of Florida, nor the Great Dipper in Patagonia. For people in the United States and Southern Europe, the October evening sky presents its brighter stars about as follows: In the northwest the glowing Arcturus is about to set, while in the southwest the duskier red Antares in the constellation of the Scorpion is also nearly setting. Somewhat west of the zenith stands the brilliant white star Vega, and towards the east and south from Vega, in the embrace of the Milky Way, lies the slightly fainter white star Altair. Farther east, somewhat farther north than Vega, and in brightness half-way between Altair and the pole star, is Deneb, another white one. A very brilliant far-northern star is the yellowish Capella, seen a good way to the northeast of Deneb. Of all the bright northern stars, Capella is most like our sun.

Towards the southeast and not well seen early in the October evening lies a field of bright gems. Aldebaran, which is the red star in the V-shaped group, rises earliest of them, and has gotten well up in the eastern sky. Southeast of him lies the great group of Orion whose central figure is like a square with the giant red star Betelgeuse to the north, and the giant blue star Rigel to the south of it. Farther south and later rising is the white Sirius, brightest of all the stars of the entire heavens. Rising still later, and about as far north as Betelgeuse, comes Procyon, slightly yellowish of tinge. Rising soon after Procyon but farther north, comes the reddish Pollux, the brighter of the twins Castor and Pollux. Last of all of the first magnitude stars of our northern October sky to rise is Regulus, in the constellation of the Lion, which comes up a little north of east at about two o'clock in the morning on October 15.

Had we traveled in the southern Hemisphere, for instance in South Australia or New Zealand, Deneb and Capella must have been dropped from our list of bright stars, along with the pole star, as too northerly for observation. But the yellow Alpha Centauri, the nearest of all the stars and very like our sun, would replace Capella. In the early evening it would lie in the southwest. Its blue companion, Beta Centauri, would lie still nearer the horizon and farther south. Nearly overhead would be the white star Fomalhaut, as bright as Deneb. The brilliant blue Achernar would be directly south at midnight, and following it five hours later, a little farther north, would come Canopus, next to Sirius the brightest star of all. The Orion stars would have moved to the northeastern quarter. We should see at this time of the year the two bright bluish stars, Alpha Crucis and Beta Crucis, of the constellation Southern Cross, far down near the southwest horizon in the evening and in the southeast several hours before sunrise. In October, Spica, alone of all the first magnitude stars, would be too near the sun and lost in the morning or evening twilight.

These twenty-one brightest stars and the five brightest planets which we have named should be well known to everybody. A table will be found in the Appendix which gives various facts about them.

Stretching diagonally across the sky from northeast to southwest, and passing almost directly overhead in the October evenings, lies the Milky Way. Like the bright stars, it marches from east to west throughout the night, but some parts of it are always in view, for it is a belt that completely encircles the heavens.

As we watch the stars moving through the night, we see that they move by less and less distances and more and more aslant to the horizon, as we look farther and farther north, till presently we find some that neither rise nor set, but describe large circles in the northern sky. Looking towards the center of these circles, we find the stars moving less and less till finally, at the pole star, the eye can scarcely see motion at all, unless we guide our view very accurately by some fixed objects in a line, such as stones or houses.

So the sun and all the stars move across our sky from east to west, or from west to east, according as they are south or north of the pole star. The reason for it is that our round earth is itself rotating eastwardly, one rotation in twenty-four hours, about its axis which points nearly towards the pole star. Of course we know that the

earth has no real solid axis, with bearings, like a bicycle wheel. It rests upon nothing, and spins thereon without ever losing its place!

As we watch the stars going by over our heads, they seem innumerable. But every one of them that the eye can see has long ago been numbered and given a place, each with its identifications and many descriptive annotations, in the astronomical catalogues. The naked-eye stars that can be seen in one view of the heavens are, in fact, hardly more numerous than the people in a large full theatre. All of them that the sharpest eye can see unaided in both the northern and southern hemispheres, and in the dark and daylight sides of the earth combined, hardly exceed five thousand.

But it is far otherwise when we search the sky with a giant telescope and photography. For the Milky Way, that looks like a dim cloud, resolves itself into a perfect host of individual stars. It has been computed, for of course no one's life-time would be long enough to examine them every one, that all of the stars which could be photographed with our largest instruments would be nearly as many as the human inhabitants of our earth, or perhaps a thousand millions. Occasionally, as we watch, we see what appear to be little stars dart out from among their neighbors, rush a long way through the sky and disappear, sometimes leaving behind a short-lived train of light. These shooting stars, or meteors, are not really stars at all, but are little cold bits of dust or metal which belong, at least temporarily, not among the stars, but among the planets. They are attached to the family of our sun, and happen, in their courses, to overtake or be overtaken by our earth's atmosphere. Rushing through the air with enormous speeds, they quickly become white hot, and burn up like iron heated too hot in the blacksmith's forge. Most of them are quite consumed in the upper air, but some very large ones reach the earth. Admiral Peary even found one of many tons weight on one of his Greenland expeditions, and brought it to the American Museum of Natural History in New York. Here, like a wild animal of the jungle caged in a zoölogical garden, this captured free tenant of boundless outer space is housed up to amuse and instruct the people.

Thousands of years have passed since men first looked upon the stars. Yet we know that their order has apparently changed but little in all that time. Probably there would be little of change of any kind among them that the sharpest naked-eye observer could

note if, like the legendary Wandering Jew, he had lived from the time of Christ until now. Stars that were brightest then are brightest now, as we know on the best of grounds.

It is true that once every few years there comes to view what astronomers call a new star. Thus, in February, 1901, there blazed up in the northern constellation of Perseus a star, till then obscure, which for a few days rivaled all but the very brightest of our list of twenty-one. But it soon faded and is now visible only to fair-sized telescopes. Again, in June, 1918, a new star arose near Altair, in the constellation Aquila, which briefly surpassed all but Sirius in brightness. But this also has faded to dimness. It is a curious thought that these new stars of the twentieth century are really so far away that their light, our swiftest messenger, traveling 186,000 miles each second, had been on the way some centuries. These stars had really flashed forth and faded back to insignificance before Cromwell was Lord Protector of England.

Before leaving our lonely hill of observation we shall probably ask ourselves the question whether among this myriad of objects which are within the visible creation, there is not, besides our world, some other, or perhaps many other abodes of thoughtful life similar to ours. Were there but beings like ourselves on other worlds, and could there be some wireless communication established between us and them, what a breathless interest we should have in learning from them of their forms of society, their governments, their religions, the scenes with which they are surrounded, and, in a word, the whole conditions of races of intelligent beings developed independently from ourselves!

CHAPTER II

SOME FAMOUS ASTRONOMERS AND FAMOUS INSTRUMENTS

The ancient astronomers looked upon the stars as if they were diamond-like gleams of light fixed on the inside of a hollow azure sphere. After astronomy became a science it was necessary to take a census of the sky by enumerating in catalogues the positions and magnitudes of the stars. The fascinating aim of modern astronomy is to give life to this flat picture by applying the latest discoveries in physics and chemistry, to discover what the stars are, how they took their origin, and what are their motions and what these signify, in short to solve the riddle of the universe. The earth is small and insignificant when compared with the colossal dimensions of the universe.

Hipparchus. — There is no more fascinating study in the whole of science than to trace the history of astronomy from the time of the early Babylonians and to watch the torch of knowledge, sometimes waning, but on the whole glowing ever more and more brightly as it was passed from one generation of astronomers to the succeeding one. The greatest observer among the early astronomers was Hipparchus who worked about 150 to 125 B.C. He catalogued 1026 stars, founded the science of trigonometry, fixed positions on the earth by latitude and longitude, determined the length of the year, the periods of revolution of the five great planets around the sun, and the obliquity of the ecliptic, that is, the inclination of the earth's equator to its plane of revolution about the sun. He found the eccentricity of the earth's orbit, or in other words how far it is from being circular; measured the distance of the moon roughly, and discovered the precession of the equinoxes. The intersection of the celestial equator and the ecliptic (in the plane of which the sun moves) is shifting constantly to meet the sun as it moves eastward in its annual journey among the stars. This last discovery of his waited two thousand years for its explanation.

Ptolemy. — Nearly three centuries went by from Hipparchus to Ptolemy of Alexandria, who flourished 127 to 151 A.D. He

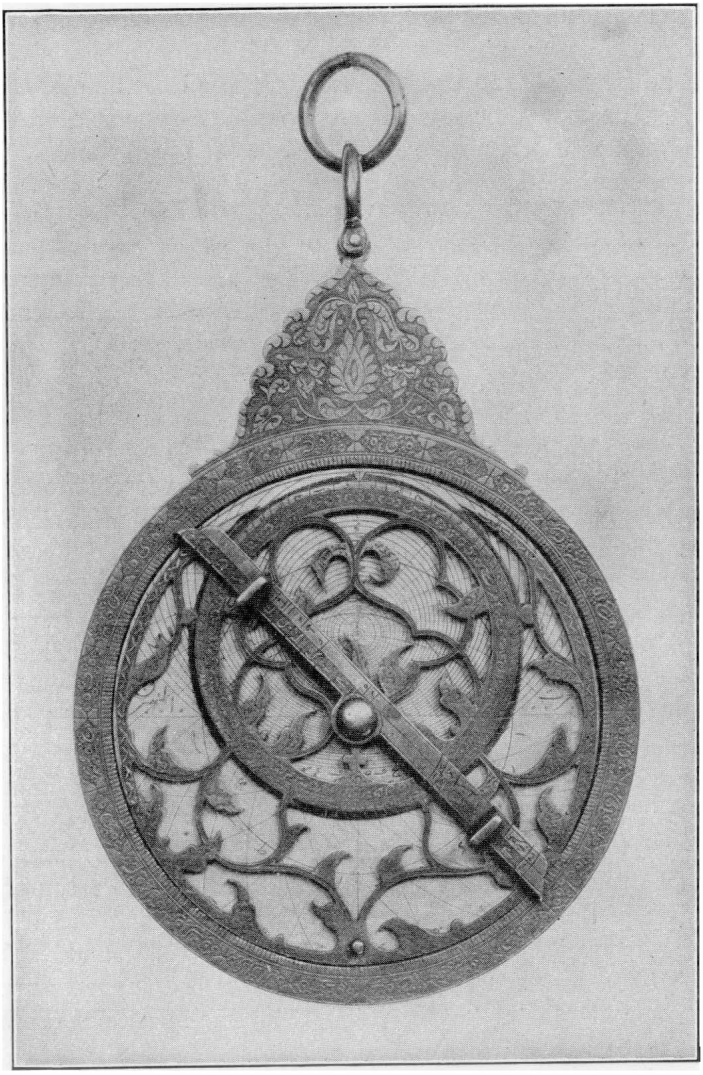

PLATE I. A PERSIAN ASTROLABE.

was not as great an observer as Hipparchus, but he collected all knowledge in the famous work which the Arabs called " Almagest." He describes the earth as a sphere in the center of the heavens, which he assumes are very far away compared to the size of the earth. " Though some say the earth turns on its axis, and truly this simplifies theory, yet," says Ptolemy, " it is ridiculous." The heavens, he points out, have two principal motions. One carries them around the earth uniformly from east to west each day, the other is peculiar to some stars only (he means the planets, of course) and is contrary to the first and about different axes. Ptolemy gives mathematical tables useful for trigonometry which he computed by an elegant method, and goes on with a great number of facts such as the obliquity of the ecliptic, the length of day and height of the sun at different times and places. Recognizing the earth as the center of things and immovable, he was at pains to work out an elaborate theory of epicycles and eccentrics to explain the apparent motions of the sun, moon and planets. He discusses the eclipse observations of the Chaldeans and his own, and sums up the knowledge of how to calculate eclipses. Ptolemy has preserved for us the catalogue of Hipparchus, giving the positions of the fixed stars, their arrangement in constellations, and their brightness.

Ptolemy's " Almagest " ruled the astronomical thought of the next thousand years and more, till there came the century of the geniuses. Where else can we find within a single century another such group of men of accomplishment as this! Gutenberg (1398–1468) who invented printing; Columbus (1446–1506) who discovered a new world; Copernicus (1473–1543) who reconceived the place of the earth in the universe; Leonardo da Vinci (1452–1519), Michelangelo (1475–1564), Titian (1477–1576), and Raphael (1483–1520), a quartet whose achievements it is unnecessary to rehearse, and Martin Luther (1483–1546) the apostle of the Reformation.

Copernicus, a physician and priest of a small place in Poland, spent his life in ministering to the poor and thinking of great things. He conceived that the rising and setting of the sun and stars are the consequence of a daily rotation of our earth upon an axis inclined toward the polar star, and that the earth and the great planets, Mercury, Venus, Mars, Jupiter, and Saturn (all that were