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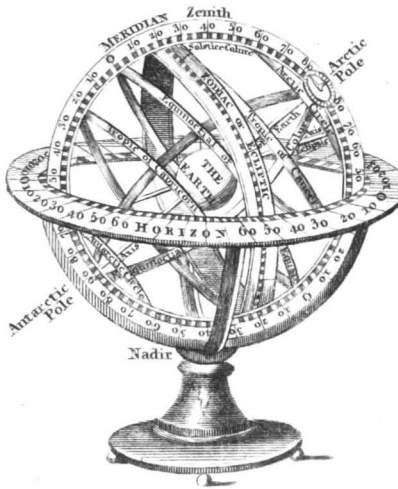

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LALANDE, Joseph Jérôme le Français de

LADIES' ASTRONOMY.

Translated from the French of

JEROME DE LALANDE,

BY

MRS. W. PENGREE.

LONDON:

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THE

TRANSLATOR'S PREFACE.

THE following outline of the history and science of astronomy, appears particularly adapted to the use of ladies who may not have leisure to enter upon a regular course of study. It is however presumed, that, as a companion to more practical works, this little volume will be found not less conducive to the progress of those who may be desirous to acquire a further knowledge of the subject; being, in a great measure, divested of the difficulties which often prove so discouraging in astronomical pursuits.

The translator is aware, that to render justice to the known merits of the author,

required an abler pen; but the desire of placing in the hands of her own pupils, a work in their native language, so well calculated to promote a taste for this interesting science, induced her to make the attempt, and she will deem herself happy, if she has in any degree contributed to its general utility.

Mr. de Lalande's explanation of mythology by means of the stars, is omitted, as not being immediately connected with the subject; and two chapters are substituted on the five newly-discovered planets, extracted from the works of Messrs. de Lalande, Montjoye, and other authors.

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HISTORICAL PREFACE.

THE spectacle of the heavens is an object of such general interest, that it ought necessarily to form a part of every regular course of instruction. We accordingly see ladies taking a lively interest in it, putting questions on astronomical subjects, and regretting their inability to pursue its study. But it is very difficult to acquire any adequate knowledge of the science, without diagrams and calculations: I shall, therefore, in this work give only a general picture of astronomy, and the great phenomena which it presents; with the curious discoveries made by astronomers, and the means by which they have arrived at con-

clusions, so surprising to those who have not acquired the first rudiments.

Confining myself within these limits, I cannot refer to my large *Treatise on Astronomy*, (in three volumes quarto,) nor to the *Abridgment*, (in one volume octavo,) as even the latter would require some previous knowledge of geometry and mathematics, which I have thought best to avoid in this work. Perhaps I ought to have given the first elements of the mathematics; but I feared it might appear too complicated for the generality of those for whom this work is intended, and whom it is my wish not to discourage on the borders of the science.

The *Plurality of Worlds*, by Fontenelle, published in 1686, which is still very generally read, might, perhaps, have served me for a model; omitting only the hypothetical and obsolete, (such, for instance, as the vortices,) and correcting some errors, which must be visible to every one, particularly in his observations upon comets. But that work does not enter sufficiently into the subject; and, with whatever attention it be read, but a very

imperfect idea of the constitution of the heavens will be obtained.

I shall begin this treatise in the same method I adopted in my larger work; because, after mature consideration, I cannot find any thing more suitable to the object I have in view: requesting only from my fair readers, (after the example of Fontenelle,) "that degree of application which they would find necessary in perusing the *Princess of Cleves*, if they are desirous of becoming acquainted with its beauties." It is true, that the subject of this treatise may not be so familiar to them; but it is not less intelligible, and I am confident that, after a second reading, at most, it will be perfectly understood.

My object, however, is different from that of Fontenelle, who was desirous of bringing astronomy to such a point, as would neither be too dry for the generality of his readers, nor too trifling for the learned. But, as he himself says, that, by seeking to adapt this science to every one, it might be found suitable to no one, I shall devote this work exclusively to the ladies.

We have, already, many instances of females, who have evinced a laudable spirit of inquiry, and great perseverance in the pursuit of this science. The beautiful Hypatia, who was assassinated by the clergy at Alexandria, in the year 415, taught astronomy there, and composed several works. Maria Cunitz, the daughter of a physician of Silesia, published some astronomical tables in 1650; and Maria Claire Eimart Muller, the wife and daughter of two well-known astronomers, was also well versed in this science. In 1680, Joanna Dumée gave lectures on the Copernican system; and the wife of Hevelius made observations with him. Manfredi's sister calculated the Ephemeris of Boulogne; as did Kirch's three sisters, for a length of time, that of Berlin: his wife, also, published, in 1712, a work on astronomy. The Marchioness du Chatelet translated and published the works of Newton; and the Countess of Purinina, to whom the passage in Scripture, "*Una mulier fuit confusionem genti,*" was justly applied, founded an observatory in Poland. Madame Lepaute, who died in 1788, calculated the

ephemeris of the Academy for more than ten years; and the widow of Mr. Edwards is now employed in England, in the composition of the *Nautical Almanack.* Madame du Piery, the first lady who taught astronomy at Paris, made several calculations of eclipses, to ascertain the Moon's motion; and Miss Caroline Herschel, whose proficiency in the science is so well known, has discovered five comets. Madame la Duchesse de Gotha does not wish to be quoted, but she has, likewise, made several calculations; and my niece, Françoise de Lalande, assists her husband in his observations, whence she draws her conclusions by calculations. She has reduced ten thousand stars, and has published three hundred pages of *Horary Tables for the Navy;* an immense work for one of her age and sex, which may be found in my *Abridgment of Navigation.*

We have here given sufficient instances of females who have distinguished themselves, even under every disadvantage of education and prejudice, to convince us that their abilities are not inferior, even to those of our sex

who have attained the highest celebrity in the sciences.

The utility of astronomy, independently of the sublime spectacle which it presents to us, and in which all well-informed persons take an interest, is so generally acknowledged, that it requires but little comment. By the aid of astronomy, geography and navigation have united the furthest extremities of the globe; and by its means, the calendar and chronology have been regulated, sun-dials constructed, &c.

The return of the seasons and meteorological predictions may, hereafter, become a very important object of astronomy, but they are as yet imperfectly understood. There is reason, however, to believe that a similarity of seasons, as well as eclipses, returns nearly every eighteen years; an idea of which I have sometimes availed myself, with success, in the Paris journals, to satisfy the public mind on the apparent uncertainty of the seasons.

We have, in history, many instances of the ill-effects of ignorance in the science of astronomy, as experienced by whole nations,

Nicias, an Athenian general, having determined to quit Sicily, was so dismayed at an eclipse of the Moon, that he suffered the favourable moment to escape him, and his own death, with the ruin of his army, ensued: an event so fatal to the Athenians, that it is from that period they date the decline of their power. Even the troops of Alexander were thrown into the greatest alarm, by an eclipse of the Moon, before the battle of Arbela, of which he sent to acquaint the Egyptian astronomers, and commanded sacrifices to be offered to the Sun, the Moon, and the Earth, as divinities who had occasioned the eclipse.

We find, on the contrary, other generals, to whom the knowledge of astronomy proved particularly useful. When Pericles commanded the Athenian fleet, there happened an eclipse of the Sun, which occasioned general consternation. The pilot himself trembled; but Pericles removed his fears by this very simple comparison: covering the pilot's eyes with the end of his cloak, "Thinkest thou," said he, "that what I now do is a sign of

misfortune?" "No, certainly not," replied the pilot. "And yet," resumed Pericles, "this is an eclipse to thee: it differs from that which thou hast seen only in this—that the Moon, being much larger than my cloak, hides the Sun from a greater number of persons."

Agathocles, king of Syracuse, during a war in Africa, perceived, at a critical moment, that terror was widely spreading through his army at the sight of an eclipse; but, presenting himself before his soldiers, and explaining the cause of this alarming phenomenon, he succeeded in dissipating their fears.

Tacitus, also, speaks of an eclipse, of which Drasus availed himself, to appease a revolt. And instances of this kind are mentioned of Sulpitius Gallus, a lieutenant of Paulus Emilius, in the war against Perseus; as also of Dion, king of Sicily. Christopher Columbus, likewise, when at Jamaica, taking advantage of an eclipse of the Moon, which he knew would happen, compelled the savages to deliver him from a very critical situation; and I have myself been frequently enabled, by my knowledge of astronomy, to relieve the public

mind from those terrors, which the predictions of astrologers, and the appearance of comets, have but too frequently occasioned. In 1186, there was a conjunction of all the planets, which, it was said, portended unheard-of calamities; yet no extraordinary event signalized that year. In 1773, the Parisians were thrown into the greatest alarm, from the expectation of a comet, for which there was no foundation; and this inconceivable panic extended itself even to other countries.

Having given some idea of the utility and advantages of astronomy, we will consider the history and progress of this science. According to Mr. Bailly, the origin of astronomy may be traced to an antediluvian people, now forgotten, but from whom some fragments of astronomical information have been preserved. Other historians ascribe it to the Egyptians and Chaldeans. It was in Egypt that Plato and Eudoxus conceived those ideas with which they enriched Greece, 370 years before the vulgar era; and Cepheus and Cassiopeia, were natives of Ethiopia, which fixes the origin of the constellations in the south of Egypt. But

the Egyptians carefully concealed their knowledge; all traces of which were lost with their government, religion, and language. It was among the Babylonians, that Hipparchus found the most ancient observations of which he could avail himself, to determine the Moon's motion. The first of these is an eclipse of the Moon, observed at Babylon 721 years before the Christian era; and Ptolemy preserved many others, up to the year 492 before our era, after which period, the kings of Persia becoming masters of Babylon, and not residing there, less emulation was excited, and the reputation of the sciences consequently declined.

The Greeks say, that Thales, of Miletus in Ionia, about 600 years before our era, was the first who determined the Sun's motion, and taught the Greeks the cause of eclipses. Herodotus even asserts, that he predicted an eclipse; this, however, he could have done only from his knowledge of their regular return every eighteen years, which he must have acquired either in Egypt or Chaldea. About

300 years before the Christian era, a revolution took place in astronomy, under the protection of the Ptolemies, kings of Egypt. The first Greeks who cultivated this science at Alexandria, were Timocharis and Aristillus. Ptolemy, in his *Almagest*, assures us, that Hipparchus had availed himself of their observations, imperfect as they were; and that he had, by their means, discovered the movement of the stars in longitude. Ptolemy himself quotes many of their observations; the most ancient of which was made in the year 294 before our era. Timocharis saw the northern edge of the Moon, touch the northern star in the brow of the Scorpion. This observation is one of the best, of which we can avail ourselves, to determine the motion of the fixed stars.

Ptolemy Philadelphia succeeded Ptolemy son of Lagus, about the year 283. He was a prince well versed in the sciences, and the avowed protector of all those by whom they were cultivated. He invited the learned to his capital, not only from Greece, but other countries; appropriated apartments in his pa-

lace to their use; assigned them an honourable provision; and thus furnished them with the means of applying themselves successfully to the sciences. The Museum, or College of Alexandria, is celebrated by Strabo. The emulation which prevailed at that period in Egypt, still existed at the time of the invasion of the Saracens, in the year 634 of our era; though the sciences had greatly declined, even since Strabo's time, who lived in the reign of Augustus.

Aristarchus of Samos, about 264 years before the vulgar era, taught the motion of the Earth round the Sun, of which, however, Philolaus had spoken before him. He conceived an ingenious method to find the distance of the Sun from the Earth, by supposing that of the Moon to be known, which is, in fact, the easiest to ascertain.

Eratosthenes, born at Cyrene, 276 years before our era, was invited by Ptolemy Evergetes, from Athens to Alexandria, where he was appointed to superintend the royal library. By his direction an armillary circle of bronze, or a great circle in the form of a ring, was

erected in the Portico, with an inclination corresponding to that of the celestial equator, to ascertain the exact time when the Sun was in the equinox. Hipparchus availed himself of it, in the following century, in making his observations, which are still considered very valuable.

Eratosthenes was also the first who attempted to measure the circumference of the Earth.

Hipparchus appeared at Alexandria about the year 160 before our era. He was the most intelligent and indefatigable astronomer, whose name tradition has transmitted to us. Real astronomy may be said to have begun with him: he collected the most ancient observations, to which he added many of his own; and having discovered that the motions of the planets were not uniform, he even determined their irregularities, at least as regards the Sun and Moon, and ascertained the true length of the year. He also rectified the measurement of the Earth, as given by Eratosthenes.

Having discovered a new star, which ap-

peared in his time, and being persuaded that these phenomena might frequently occur, and that those stars might have a motion which are reputed fixed, he, as Pliny expresses it, "by a godlike enterprize, transmitted to posterity the enumeration of the stars of heaven; whence, having ascertained their situations, with instruments of his own invention, by which he was enabled to mark their places and magnitudes, he afforded the means of discovering, in future, whether any stars disappeared, and became again visible; or if they changed their situations, magnitudes, or light. Thus, as it were, leaving the heavens as an inheritance to all those who were capable of profiting by the gift."

This catalogue of Hipparchus contains 1022 stars, with their positions for the year 128 before the vulgar era; which great work was happily preserved by Ptolemy.

Hipparchus, on comparing his observations on the Virgin's spike, with those of Timocharis, made a century before, was the first who discovered that the stars changed their positions, and appeared to advance slowly from west to

east, in regard to the equinoctial point. This is called the precession of the equinoxes, by means of which the signs of the zodiac, or the points of the annual revolution of the Sun, make the circuit of the heavens and the constellations, in the space of 25,000 years.

Since the observations and theories of Hipparchus, we meet with nothing useful to the progress of astronomy, except the works of Ptolemy, an astronomer of Alexandria, who lived between the years 125 and 141 of the vulgar era. His *Almagest* is the only important work that is left us of ancient astronomy; and though his system and observations are but little esteemed, we are frequently obliged to have recourse to them. If, therefore, the theories on the motions of the planets, which his work contains, are his own, this author has rendered essential service to astronomy.

During the succeeding ages, the cultivation of this science was greatly neglected: it appears to have been confined to mere translations and comments upon the works of Pto-

lemy. We meet only with some Arabian observations, made under the Caliph Almamoun, who reigned at Bagdad in the year 814; some few of Albategnius, an Arabian prince, who lived about the end of the same century; and of Ulug-Beg, grandson of the great Tamerlane, who reigned in Bactriana about the year 1437. This prince has left us a catalogue of stars, which is still much esteemed.

Astronomy made no very remarkable progress till the time of Copernicus, a native of Prussia Royal, born in 1472. From the year 1507, he began to consider the imperfection and complication of the hypothesis at that time admitted, to explain the motions of the planets; whence he perceived that they might be greatly simplified, by supposing that the Earth turned round the Sun. Fearing, however, to announce so extraordinary a principle, without affording positive demonstration, he determined to examine each planet individually, and to ascertain its motion, that he might be enabled to construct some more correct tables than those of Ptolemy. He then ascer-

tained, beyond the possibility of doubt, that all irregularities were perfectly explained by his new system. In the year 1530, he concluded his celebrated work, *De Revolutionibus Orbium Cœlestium;* but it was long before he ventured to present it to the world, and the work did not appear till the 24th of May, 1543, the very day on which Copernicus died.

It is to this author we are indebted for those luminous ideas, and intense labours, which have so materially changed the face of astronomy, and led to its further progress. But Tycho Brahé, the greatest astronomer known in those days, was the first who, by his exactness and the number of his observations, revived the study of this science. On these, all the theories, tables, and discoveries of Kepler were founded; and their names, added to those of Hipparchus and Copernicus, well deserve to be immortalized. Tycho, who studied at Copenhagen, was born on the 13th of December, 1546, in the province of Scania, in Denmark. He was of an illustrious family, still existing in Sweden, under the name of Brahé,

and connected with that of Lowendal. Finding that the eclipse of the Sun, on the 21st of August, 1560, happened exactly as astronomers had foretold, he conceived, from that moment, the most ardent desire to be capable of making similar predictions.

Frederick the First, king of Denmark, gave him the island of Huen, situated in the Baltic Sea, opposite Copenhagen, where, from the year 1582 to 1597, he made an immense number of observations. He determined the positions of the stars, observed the refractions and inequalities in the Moon, and furnished Kepler with the means of discovering the laws of motion of the planets, and of constructing a set of entirely new tables.

But Kepler, by the admirable conclusions which he drew from these observations, acquired even more reputation than Tycho Brahé. Kepler was born in 1571, in the duchy of Wirtemberg. He discovered the laws of the celestial motions, and composed new tables of the motions of the planets, which were used by all astronomers, from the year 1626 to the end of the seventeenth century.

The invention of telescopes, in 1609, gave rise to fresh discoveries. Galileo, availing himself of it at Florence, to observe the planets, perceived that there were mountains in the Moon, spots in the Sun, and a ring which encircles Saturn; that Venus was often horned like the Moon, and that Jupiter was accompanied by four little planets, which are called the satellites of Jupiter.

Hevelius, a magistrate of Dantzic, born in 1611, made, between the year 1641 and 1685, an immense number of observations. He composed a new catalogue of the stars, and his work is still valuable to the astronomer: but it is now become so exceedingly scarce, that it is to be found only in very extensive libraries; the entire edition having been consumed, in a fire occasioned by the treachery of a servant.

The establishment of the Academy of Sciences, at Paris, which met for the first time on the 22nd of December, 1666, forms one of the most memorable epochas in the history of astronomy, as well as in that of the other sciences which it embraces. It is to the taste

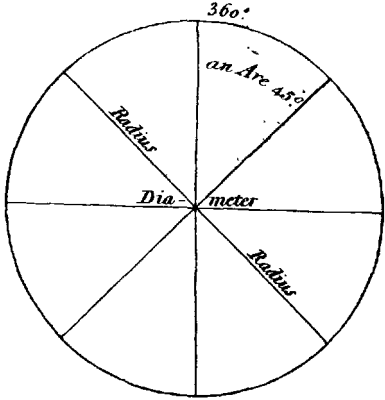
for literary societies, which had commenced in France long before that period, that we may trace the progress of the *belles lettres*, the sciences, and philosophy. Bacon, who died in 1626, speaks with rapture of these societies. There were some of this description established by Père Marsenne, in 1638. But it was the great Colbert who sought out and drew together the learned in every branch of the sciences, of whom he composed our celebrated Academy. Astronomy has there been brought to great perfection. Among the most important of their discoveries, we consider the satellites of Saturn, the propagation of light, the magnitude and figure of the Earth, the application of pendulums to clocks, that of telescopes to quadrants in 1668, and that of micrometers to telescopes. All the principal points of astronomy were there discussed and established. In these are comprised, the theory of the Sun and Moon, their inequalities, diameters, and parallaxes; refraction, the obliquity of the ecliptic, and the irregularities of the satellites of Jupiter.

Huygens, Picard, the celebrated Cassini, who was invited to Paris in 1669, and Lahire, bore a principal part in these discussions.

But we owe to John Flamstead, a celebrated astronomer, and Member of the Royal Society of London, established about the same time, the largest catalogue of stars that had ever been published, which appeared in 1712. And we are indebted to Halley, who succeeded him, among other things, for the first prediction of the return of a comet, which was verified fifty-four years afterwards; that is to say, in 1759.

All discoveries in astronomy were, however, eclipsed by those of Newton; who ascertained and published, in 1687, the fundamental law of the universe, or of universal attraction, by which all the phenomena of nature were explained: the motions of the planets, the inequalities of the Moon, the spheroidical figure of the Earth, the return of comets, the flux and reflux of the tides; and even the cause of the precession of the equinoxes, which was one of the most obscure and complicated of these phenomena.

But since Newton's time, every branch of astronomy has been brought to still greater perfection. The figure of the Earth, the inequalities of the Moon, of the planets, and the satellites of Jupiter, the small motions of the stars, the return of the comet in 1759, and the real distances of the planets from the Sun and the Earth, have been correctly ascertained; to which we may add, the discovery of five new planets, whose existence was not even suspected. All these subjects will be explained in the little volume which I now offer to my fair readers. May they be induced by its perusal, to seek, in a more extensive work, for a further knowledge of the sublime spectacle of the universe.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PRELIMINARY EXPLANATION.

On the Measure of Angles.

AS all astronomy is founded on the measure of angles, or degrees, it will be necessary, in the first instance, to explain in what manner this measurement is made.

In the preceding plate, a circle is described, the circumference of which is divided into equal parts. We have represented only eight, that the figure may not appear confused. In each of these divisions there are forty-five degrees; it being generally agreed to divide the circle into three hundred and sixty degrees.

The arc of forty-five degrees shows the inclination of the two lines, or radii, between which they are comprised; which inclination, or angle, is also said to be forty-five degrees: and

if these two radii point to two stars, we say that those stars are forty-five degrees distant from each other.

It is with a circle thus divided, that the degrees and sections in the heavens are measured. This is the basis of all astronomy; and the accuracy of every observation depends upon that of the divisions of the circles, or of the instruments employed for the purpose. These divisions are sometimes carried as far as the 3600th part of a degree, upon a circle of seven or eight feet diameter; upon which we are thus enabled to measure the minutes and seconds in the heavens, although the celestial circles contain several millions of leagues; but the seconds in the heavens being at so great a distance, appear to us only like those on our instruments.

If we were to divide the circle into three hundred and sixty parts, it would show all the degrees; but, to render these divisions sufficiently distinct, the circle must be at least four inches in diameter. We should then perceive that a degree is equal in length to the fifty-seventh part of the radius, or distance

from the circumference to the centre of the circle. This remark is very important, and I shall have occasion to refer to it hereafter, in explaining the method by which the distances and magnitudes of the stars are to be found.

An arc of three degrees, which is nineteen times less than the radius of the circle, or thirty-eight times less than its diameter, would be sufficient to show that the arc of one degree, had it been possible to have marked it, would be the fifty-seventh part of the radius, or of half the diameter of the circle.

LADIES' ASTRONOMY.

CHAPTER THE FIRST.

On the apparent diurnal Motion of the heavenly Bodies.

TO form a correct idea of the heavens in a fine night, we must first consider the diurnal motion common to all the celestial bodies, as they appear to revolve round the two poles, or the axis of the world, which is represented by the celestial globe, now in the hands of every well-informed person.

The Great Bear, so called by astronomers, but which country people know by the name of Charles's Wain, is a constellation composed of seven stars, which may always be seen towards the north, though they are sometimes higher

or lower, according to the time of the year at which the observation is made. In the month of April, about nine o'clock in the evening, we see them nearly over our heads, or at our zenith. In the month of October they are, on the contrary, very low, or near the horizon, which is a sufficient indication of their circular motion. It therefore only remains to determine round what point this motion is made. It is round that point which is in the centre of their course, or circle, and which is nearly at half the height from the horizon to the zenith; that is to say, from the circle which surrounds us and which limits our sight, to the summit of the heavens, or that point which is directly over our heads.

It is by means of this circulation, or revolution, that the Great Bear appears to rise, and afterwards to descend towards the horizon; which, if we make the observation several times in the same night, will be as evident, as that the sun rises in the morning and sets in the evening. Hence we may conclude, that the stars revolve, or appear to revolve, round us every day, as well as the Sun.

The point of the heavens round which this motion is made, is marked by the Polar Star, which may always be found by seeking, towards the north, for a star that does not visibly change its place in the course of the night, this being the case only with the Polar Star. But as for this purpose it would be necessary to select several, and to observe each of them separately for many hours, it will, perhaps, be better to have recourse to the Great Bear, in which are two stars marked on the globe α and β, and which point in nearly a direct line to the Polar Star: observing only to follow this line, to the right in summer, to the left in winter; upwards in autumn, and downwards in the spring.

When the Polar Star* is known, which may be considered as the centre of general motion, it may easily be conceived in what manner the different stars circulate round it. Those which are very near the pole, describe small circles,

* We take the Polar Star for the pole itself, because it does not differ more than two degrees, which is scarcely visible to the naked eye.

the course of each being extended in proportion to its distance from the pole; and when these circles become sufficiently large to reach the horizon, the stars set, till which time they appear all night.

The Sun rises and sets every day, because he is at so great a distance from the Polar Star, that his diurnal circle extends beyond the space from the pole to the horizon; which is the case also with the Moon and all the other planets.

The heavens resemble a ball, or globe, which, in turning, must necessarily have two points, or poles, round which this motion is made. Of this we may easily satisfy ourselves, by making the experiment with any ball, or artificial globe.

Of the two celestial poles, we see only one, which is the North or Arctic Pole: the other, which is opposite to it, and which is called the South or Antarctic Pole, is invisible to us, because it is as much depressed below the horizon in the south, as that in the north is elevated above it.

In the centre between these two poles we may imagine a circle, which is the Equator,

represented on the globe as equally distant in every part from each of the two poles, and as dividing the world into two equal hemispheres, one of which is the northern, and is that which we inhabit; the other, the southern, containing a part of Africa and America.

The Equator is used in astronomy to denote the declinations of the Sun, the planets, and the stars. The Sun's declination in the summer, at noon, is twenty-three degrees and a half above the Equator; and in winter, the same number of degrees below it. Thus, we say that the Sun's declination is twenty-three degrees and a half north in the summer, or twenty-three and a half south in the winter.

The Meridian is the circle which rises from the south directly over our heads, and which, passing over the poles, makes the whole circle of the heavens, dividing the day into two equal parts.

The Pole, with respect to us, is elevated towards the north, and the Equator towards the south. The degree of this elevation, which

was observed by astronomers more than 2000 years ago, must not pass unnoticed here.

The medium between the greatest altitude and depression, designates the situation of the Pole. At Paris, it is elevated forty-nine degrees, which is therefore forty-nine degrees from the Equator. This distance, which is called the latitude of a place, increases from the Equator towards the North and South Poles, and may always be determined by the altitude of the Sun and that of the Pole.

When a sufficient knowledge of the latitudes of places is acquired, it will be necessary to make ourselves acquainted with their longitudes. These are designated by the diurnal motion of the Sun, whose revolution round the earth every twenty-four hours, gives noon to all countries successively, from east to west*.

In travelling due east or west, we remain in the same latitude, but we change our longitude. In going eastward from Paris, to

* The longitude of a place is its distance eastward, or westward, from the first meridian reckoned on the equator.

Vienna, for instance, we should change our longitude fifteen degrees, and should have noon an hour earlier; because, in proceeding eastward, we meet the sun sooner, in the proportion of an hour for every fifteen degrees. Hence a traveller making a voyage round the world in an easterly direction, would find, on arriving again at the place whence he set out, that he had gained twenty-four hours, or one whole day; and he would actually have had one noon more in the same real interval of time, but his days would have been shorter in proportion.

Another traveller going round the world in a westerly direction, would experience a loss of time in the same ratio. This peculiarity in the calculation of time, would appear very evidently on the arrival of any vessel that had sailed round the world, if the crew had continued their own reckoning, without any reference to that of other countries, during their voyage.

For this reason, the inhabitants of the South-Sea islands, who are twelve hours distant from our meridian, must perceive that persons com-

ing from the East Indies, and those coming from America, reckon the days of the week differently; the former counting one day more. For, supposing it to be noon at Paris, it will be about six o'clock in the evening in the East Indies, and nearly the same hour in the morning in America. This circumstance appeared very extraordinary to our ancient navigators, who were for some time supposed to have been mistaken in their reckoning. Dampier, sailing westward to Mendanao, found that the inhabitants of that place counted a day more than he did; and Varenius even says, that at Macao, a maritime town in China, the Portuguese reckon a day more than the Spaniards at the Philippines, though these places are not very distant from each other, consequently, when it is Sunday at Macao, it is but Saturday at the Philippines. This difference arises from the circumstance of the Portuguese residing at Macao, having sailed thither round the Cape of Good Hope, while the Spaniards steered westward from America, and crossed the South Sea.

The Longitude in different parts of the

world may be found by means of eclipses. Let us suppose, for instance, an eclipse of the Moon to take place at Paris at midnight, and in the East Indies at six o'clock in the morning. We know that the difference between these two meridians is six hours, or a quarter of the circle over which the sun travels in twenty-four hours; that is to say, ninety degrees of longitude from Paris.

But as Eclipses seldom occur, and it is necessary that mariners should at all times be enabled to ascertain their longitude, they have recourse to another method, which is that of observing the situation of the Moon in relation to the fixed stars: when, for instance, she is forty degrees distant from a fixed star at six o'clock in the morning where they are, if they find, by consulting the *Nautical Almanack*, which had been calculated either at London or at Paris, that this same distance of the Moon from the star would take place exactly at midnight, they know their longitude to be ninety degrees, because the position of the Moon indicates a difference of six hours, which is ninety degrees.

The secret of the longitudes, as it was called, ceased to be such as soon as it was known how to calculate from the position of the Moon; but with a good time-piece, which will not vary two minutes in two months' navigation, so as to show the exact time at London, or at Paris, the longitude may be found even without any reference to the Moon.

CHAPTER THE SECOND.

On the Magnitude and Measurement of the Earth.

THE degrees of latitude observed, as we have before stated, prove the Earth to be 9000 leagues in circumference. To determine the magnitude of the Earth, by the measurement of only a part, may appear extremely difficult; but we have only to ascertain that twenty-five leagues are exactly a degree, or the three hundred and sixtieth part of the whole circumference, as that number, multiplied by 360, is 9000.

It has been ascertained, that from Paris to Amiens is twenty-five leagues. This distance was formerly measured by counting the turns of a carriage wheel, though it might have been done with less difficulty by a surveyor's chain. Some years since, it was again measured with

greater exactness, by a geometrical process, in which there could not be an error of more than three or four toises.

Near the road to Fontainbleau, on the left hand towards Ville Juif and Juvizy, two stone obelisks were erected, whose distances from each other, repeatedly measured, was found to be 5716 toises*. This space has served, by means of triangles raised on its basis, to determine the distance from Paris to Amiens, which proved to be 57,000 toises; or, to be more correct, 57,050 toises to the point where the degree terminates. For this purpose, it was necessary to fix on a toise which should be invariable, and that the measurement should be performed with the greatest exactness, in which case we may always calculate to a certainty within the twentieth part of a line; a trifling error, which would not amount to more than three toises in a degree.

That the distance from Paris to Amiens is exactly a degree, may also be ascertained by

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* A toise is about 4¾ inches more than our fathom.

observing a star which passes the zenith of Paris. This may be discovered by means of a telescope, having a plumb-line exactly parallel to its axis, so as to ascertain if it is exactly vertical, or perpendicular to the horizon. By removing the same telescope to Amiens, we shall find that the star is no longer over its centre, or at the zenith, but that it is lower by a degree; or, in other words, that the plumb-line has separated from the telescope in the proportion of one inch in fifty-seven, which answers to a degree. Of this we may convince ourselves, by describing, on an even table, a circle of fifty-seven inches radius, and dividing it into three hundred and sixty equal parts, each of which will be found to be exactly an inch. Therefore, the plumb-line being removed one degree at Amiens, the telescope, or the star which appears in its centre, will be one degree from the zenith. Consequently, the vertical line, the plumb-line, and the line of the zenith at Amiens, differ from that at Paris by one degree. This distance is, therefore, a degree on the surface of the Earth, which,

being twenty-five leagues, it necessarily follows that the whole circumference must be 9000.

This being clearly demonstrated, the diameter of the Earth may be found without difficulty; as it is nearly a third of the whole circumference, or about 2900 leagues: we are, consequently, 1450 leagues distant from the centre of the earth.

It having, therefore, been ascertained that there were 57,050 toises in a degree, it was determined by French astronomers, that the French league should be the twenty-fifth part of this length; that is to say, 2282 toises. But, except in books of science, the term *league* is very equivocal. That of Burgundy is about 3000 toises; in Languedoc it is 4000; the marine, or geographical league, is the twentieth part of a degree, or 2880 toises; and the post league is scarcely 2000. For this reason, mile-stones were placed, some years since, in the great roads leading to Paris, at the distance of 1000 toises from each other, that the term league, which was so uncertain, might be exchanged for that of mile.

The above statements suppose the Earth to

be a perfect sphere. It is, in fact, nearly so; but the difference, though trifling, has occasioned much discussion among astronomers. About the year 1666, it was observed that Jupiter was a little flattened at the poles, from the effects of the centrifugal force, of which Huygens had demonstrated the laws; and the Academy, having sent Richer to Cayenne, in 1671, ascertained that the weight of bodies was less towards the Equator than with us: an additional proof of that centrifugal force, which must tend to flatten the Earth, and which was likewise demonstrated by Newton, in his *Principia*. But to prove this to a certainty, it was necessary that the degrees of the Earth should be measured in different latitudes.

In 1735, Messrs. Godin, Bouguer, and La Condamine, were sent by the Academy to Peru; and Messrs. Maupertuis, Le Monniere, Clairaut, and others, to Lapland, where these gentlemen found that a degree of the Earth was actually greater by 669 toises, than at the former place; which sufficiently indicated that the Earth was more flattened, or less convex, towards the Poles than at the Equator: the

degrees of a circle being less in proportion as it is more curved.

It was at one time imagined that the degrees being greater towards the Poles, proved the Earth to be an oblong spheroid, or that its diameter was lengthened from the Poles, which was asserted by Cassini and others; but this was soon ascertained to be a geometrical error.

The total flattening of the Earth is $\frac{1}{334}$, by which its diameter, measured from the Poles, is eight leagues and a half less than its equatorial diameter.

CHAPTER THE THIRD.

Of the Constellations, and the Manner in which they may be known.

AS a knowledge of the names of the stars is an essential part of the study of astronomy, we will now proceed to explain the method by which the principal ones may be distinguished.

There are not more than five or six thousand stars, sufficiently visible to the naked eye, to count them; but with our best telescopes, many millions may be discovered. And even this number is nothing in comparison of those which must still be invisible to us, in the immensity of the universe.

The stars are divided into a hundred constellations. We have already explained that of the Great Bear, and will now proceed to that

of Orion, which is the most beautiful constellation to be seen in a winter's evening. It consists of three stars of equal size and brightness, in a straight line, which are called, by astronomers, Orion's Belt. These are in the centre of a large square composed of four stars, two of which are of the first magnitude. There are fifteen stars of the first magnitude: of the two in Orion, one is in the foot on our right; the other, in the shoulder to our left. When this constellation is seen in the evening towards the south, in the month of January or February, the direction of the three stars in Orion's Belt, marks, on one side, Sirius, or the Great Dog-star, the most beautiful in the heavens; and on the other, though more northerly, the Pleïades, a group of small stars; near which is the Bull's Eye, or Aldebaran, a star of the first magnitude.

A diagonal line drawn from the star in Orion's Foot, which is on our right, to those in Orion's Belt, will direct us to two stars of the second magnitude, which are in the heads of the Twins, called Castor and Pollux.

The two most northerly stars in the square

of the Great Bear, are in a line in the direction of the Goat or Capella, a star of the first magnitude, situated in the constellation of Auriga, the Charioteer.

Procyon, or the Little Dog-star, forms a triangle nearly equilateral with Sirius and Orion's Belt.

The summer constellations may be known by means of the Great Bear: the two stars α and β, to which we have before referred, to find the Polar Star, are in a direct line with the Lion, in which there is a star of the first magnitude, called Regulus, or the Lion's Heart.

The tail of the Great Bear points to a beautiful star in Bootes, called Arcturus.

To the left of the Lion, is the Virgin's Spike, forming a diagonal of the square of the Great Bear.

Lyra is a star of the first magnitude, and one of the most brilliant in the heavens; it makes nearly a right-angled triangle with Arcturus, and is also called Vega.

The Eagle, which is a little to the south of

Lyra, is remarkable for three stars in a right line, the brightest of which is in the centre.

The constellation of Pegasus, which is formed by four stars of the second magnitude, may be found by a line drawn from the two stars α and β in the Great Bear, which, passing the Polar Star, will cross the centre of the square of Pegasus.

Cassiopeia is also a constellation, opposite to the Great Bear, which never sets; it consists of six or seven remarkable stars, forming nearly the letter W.

Between Cassiopeia and the Goat, is the constellation of Perseus, in which is a singular star named Algol, whose light diminishes very visibly every three days; probably from some part of its circumference being less luminous than the rest.

The Swan is a very remarkable constellation in the form of a cross, in which there is a star of the second magnitude. A line from the Twins, passing through the Polar Star, will reach the Swan at an almost equal distance on the opposite side. There are particular seasons of the year when they may both be seen at the

same time above the horizon. The tail of the Swan is the finest star in this constellation: it is a little to the eastward of Lyra.

A line drawn from the Lion's Heart, and passing beyond the Virgin's Spike, will point to the Scorpion, which is nearly in the direction of the Ecliptic, and in which there is a star of the first magnitude, called Antares, or the Scorpion's Heart.

Fomalhaut, or the Mouth of the Southern Fish, is likewise a star of the first magnitude, which is always very low at Paris, where it never has more than ten degrees of altitude. In the beginning of November, this star passes the meridian at eight o'clock at night.

The Hydra's Heart, a star of the second magnitude, may be found by drawing a line from the last stars in the square of the Great Bear, Gamma and Delta, through the Lion's Heart. The constellation of the Hydra extends from Canis Minor to a little below the Virgin's Spike.

The Crown is a small constellation, particularly visible in the summer, between the tail of the Great Bear and the Scorpion. The rest of

this space is occupied by the constellation of Serpentarius, in which the stars are not very remarkable.

We have here given a description of the stars of the first magnitude, and a few of the second; but there are five planets which may easily be mistaken for fixed stars, and from which it is of importance to know how to distinguish them. These are Mercury, Venus, Mars, Jupiter, and Saturn.

They are as beautiful, and even more so, than the stars of the first magnitude; but they have not that scintillation which we observe in the stars. Venus, in particular, is of an extraordinary brightness when she is seen after sun-set, which is the case every nineteen months. Her appearance is then so strikingly beautiful, that she has frequently been mistaken for a new star or a comet; and she may sometimes be distinguished even in full day. This was the case in the month of February, 1790, and in April, 1793; indeed, she might frequently be seen, if we knew exactly in what point of the heavens to seek for her.

Jupiter is also very brilliant, but he shines

with a paler light. Mars is of a reddish colour. Saturn is equal in size to a star of the first magnitude; but his light is the most feeble of any of the planets, owing to his great distance from the Sun.

Until the year 1781, we were acquainted with only these five planets, when Dr. Herschel, who had constructed a very superior telescope for his own observations, perceived, by accident, amongst a number of small stars in the Twins, one which did not exactly resemble the rest, and which changed its place. In fact, it proved to be a planet, like the other five, unknown till that time, which completes its rotation in eighty-three years; but it is scarcely visible to the naked eye.

Since that time, four others have been discovered; but they are seen with difficulty, even with a telescope.

There are several stars which diminish their light periodically: one of these is in the Whale, one in the Swan, and one in Perseus; the last is called Algol, of which I have before spoken.

It is probable that those stars are not equally bright on the whole of their circumference, and that their revolution on their axes presents their light and obscure parts to us alternately.

There are, likewise, some stars which appear to have acquired their light by a sudden conflagration, and to have been afterwards extinguished. Such was the remarkable star in Cassiopeia, in 1572, which was visible during sixteen months; after which it diminished its light, without changing its position, and has never been seen since. The star which appeared in the foot of Serpentarius, in 1604, was likewise of this description.

What astonishing revolutions must we not suppose in the heavenly bodies, to explain such singular appearances!

The Via Lacteà, or Milky Way, is a large whitish zone, or belt, apparently composed of an immense number of very small stars, which cannot be distinguished by the naked eye, nor even with a common telescope; but with those of stronger powers, we may perceive a

greater number of stars in this circle than in any other part. This zone crosses the ecliptic near the two solstices, and extends itself beyond them nearly sixty degrees north and south.

The Nebulæ, which may be seen with a telescope, are whitish spots resembling the Via Lacteà, supposed to be the effect of a luminous matter, irregularly dispersed through the heavens. About a hundred of these Nebulæ were already known, when Dr. Herschel discovered, by means of his powerful telescope, that the majority of them was actually composed of masses of very small stars. He himself, however, perceived more than a thousand, in which no star was visible, though it is probable that others might be discovered with still greater magnifying powers. He has counted nearly 50,000 stars, in a space not exceeding fifteen degrees in length, and two degrees in breadth. Supposing the same proportion to exist in every other part of the heavens, there would be no less than seventy-five millions of stars visible with those telescopes.

Those meteors which appear in a fine night in our atmosphere, are sometimes erroneously termed shooting stars; but a lighted candle, seen at a distance in the night, may, with as much reason, be taken for a star: indeed, it has so much the appearance of one, that I have myself been deceived.

CHAPTER THE FOURTH.

On the apparent Motion of the Sun.

THE diurnal motion is a natural subject of observation to the astronomer, being common to all the celestial bodies, the whole of which rise and set, or at least pursue their regular course round the Pole, without changing their places or situations in respect to each other, though the time of their rising and setting varies according to the seasons. This observation leads us, in the first place, to consider the apparent annual motion of the Sun through the fixed stars.

If we observe, attentively, any fixed star towards the west, after sun-set, during several successive evenings at the same hour, we shall find its distance from the Sun gradually diminish, till at length it will totally disappear,

being lost in his rays*. It will at the same time appear evident, that it is the Sun which approaches the star, because all the stars rise and set daily in the same points of the horizon, opposite the same terrestrial objects, and always remain at the same distance from each other; whereas the Sun continually changes the points of his rising and setting, and his distance from the stars. It may be likewise observed, that the stars rise nearly four minutes earlier every day, with regard to the Sun, than on the preceding one; which leaves no doubt that it is the Sun which changes its place in respect to the stars.

This observation may be made at all times; but we must be careful not to mistake a fixed star for a planet. It has already been seen by what means the stars of the first magnitude may be known. There are, indeed, but four of these near the Sun's path, which it will not be difficult to distinguish from the planets,

* This disappearance is called the heliacal setting of a star.

though they have nearly the same appearance.

The first phenomenon, therefore, which the apparent motion of the Sun presents to us is this:—The Sun daily approaches nearer to those stars which lie to the eastward of him; and this motion from west to east, is in the proportion of nearly one degree daily, so that at the expiration of three hundred and sixty-five days, a star will be seen towards sun-set, on the same day and hour, and in the same place, in which it had appeared the preceding year. That is to say, the Sun returns exactly to the same point, in respect to the star, in that space of time, and will consequently have made one revolution, which is what astronomers term his annual motion, or revolution in the Ecliptic.

This annual motion of the Sun is only apparent to us from the degree of his elevation, and the length of the days; but by observations made in the manner we have stated, we shall find that the Sun is elevated in the summer, only because he describes a circle which is

situated obliquely in regard to us, one part of which is nearer to our zenith than the other. We have summer when the Sun is in that part of the circle nearest to us, or in the north; because at that time he is most elevated above our horizon, and continues longer so each day. If we cast our eyes on a sphere, or celestial globe, we shall perceive that the inclination of the Ecliptic to the Equator is twenty-three degrees and a half; the Sun in the summer solstice is consequently twenty-three degrees and a half above the Equator; and, on the contrary, on the 21st of December, or the winter solstice, he is the same number of degrees below it: on which day, even at noon, the Sun's greatest altitude is only eighteen degrees; and he continues but eight hours above our horizon, instead of sixteen, as in the summer solstice.

At Paris, the Sun, on the shortest day, sets at five minutes after four o'clock; and on the longest, at three minutes after eight: and during several days they continue of so equal a length, that the difference is scarcely perceptible. The day after the solstice it is not

more than one second, on the following day six seconds, and on the third thirteen seconds; for which reason, we find in our almanacks that they do not vary even a minute in length during twelve days successively.

When the Sun has passed a star in his course eastward, the star begins to appear in the morning before the Sun rises, and is then said to rise heliacally, a phenomenon to which the ancient Egyptians paid particular attention. The star called Sirius rose heliacally previously to the overflowing of the Nile, which apprized the Egyptians of the danger of the inundation and excessive heats. It is probable that this faithful and useful indication of Sirius, was the occasion of his receiving the name of the Dog-star.

The great heats of August are still called the Dog-days, though they are not now ushered in by the same star.

The annual motion of the Sun is not perfectly regular; it being more rapid in the month of January, and less so in July. This difference, accumulated from day to day,

amounts to nearly two degrees, by which the Sun is more advanced in the month of April, and less in October, than if his motion were perfectly uniform.

The ancients supposed that the Earth was not in the centre of the circle which the Sun describes, and that his course only appeared less rapid when seen from a greater distance. But Kepler, and afterwards Newton, have demonstrated that the planets do not describe circles, but that their orbits are oval, and that their motion actually increases from the effects of attraction, as they approach nearer to the Earth.

This inequality in the motion of the Sun, produces, likewise, an irregularity in the days and hours. As the Sun advances, from day to day, more towards the east, he is longer in returning to the meridian, which consequently lengthens the twenty-four hours of solar or true time. This difference is also increased at certain periods by the obliquity of the Sun's motion; for which reason, a good clock, which ought to show what is called mean time, agrees

with true time, or that which is shown by a correct sun-dial, but four days in the year*.

As it will be difficult to form a correct idea of the heavens without a celestial globe, I shall now proceed to explain the principal circles which are described on it.

The Horizon is that circle which is fixed to the pedêstal of the globe, which divides the visible from the invisible part of the heavens, and determines the rising and setting of the Sun and stars.

The Brazen Meridian, which cuts the horizon at right angles, is the circle in which the Poles are fixed, round which the globe turns, and is divided into three hundred and sixty equal parts, called degrees.

Between the two Poles, and round the middle of the globe, is the Equator, divided like-

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* The clock is faster than the Sun from the 24th of December to the 15th of April, and from the 16th of June to the 31st of August; but from the 15th of April to the 10th of June, and from the 31st of August to the 24th of December, it is slower.

See Keith on the Globes.

wise into three hundred and sixty degrees. This circle is cut obliquely by the Ecliptic, which is divided into twelve signs, each containing thirty degrees. The Sun's place in the Ecliptic is generally marked on the horizon of the globe; but where this is not the case, it may easily be known by finding on what day the Sun enters each sign, which may be seen in the following tables.

Aries, the Ram ♈, 21st of March. Spring equinox.
Taurus, the Bull ♉, 20th of April.
Gemini, the Twins ♊, 21st of May.
Cancer, the Crab ♋, 22d of June. Summer solstice.
Leo, the Lion ♌, 23rd of July.
Virgo, the Virgin ♍, 24th of August.
Libra, the Balance ♎, 23rd of September. Autumnal equinox.
Scorpio, the Scorpion ♏, 24th of October.
Sagittarius, the Archer ♐, 22d of Nov.
Capricornus, the Goat ♑, 22d of December. Winter solstice.

Aquarius, the Water-bearer ♒, 20th of January.

Pisces, the Fishes ♓, 19th of February.

The day being known on which the Sun enters the first degree of each sign, it will be easy to find his place for any other day, by observing that he advances one degree daily from the equinoctial point, or first point, Aries.

To observe the state of the heavens by means of the celestial globe, on any given day and hour, first elevate the Pole to the degree of latitude of the given place: for instance, forty-nine degrees at Paris, and fifty-one and a quarter at London; observing that the cardinal points of the globe correspond with those of the heavens, (making due allowance for the variation of the compass.) Find the Sun's place in the ecliptic for that day, and bring it to the meridian; then set the index of the hour-circle at twelve, or noon of that day, and your globe will be rectified. If you wish to observe the stars at eight o'clock in the evening, turn the globe towards the west till the index points

to eight; it will then be placed to correspond exactly with the heavens at that time, and will show all the stars that are above the horizon, either east or west, north or south.

The signs of the zodiac bear the same names as the twelve constellations, or groups of stars which compose them; but there is a distinction which it is necessary to observe. The Sun, for instance, enters Aries on the 21st of March, though he is then actually among the stars of Pisces. The stars of Aries answer to the sign of Taurus; and every two thousand years they advance a whole sign, in regard to the equinoctial points. We continue to reckon the twelve signs of the zodiac, because the beginning of the spring is always considered as the beginning of the sign Aries; but the stars of the same name which were once in that sign, and from which it derived its name, are now more advanced.

In the summer, the Sun passes from the solstice to the equinox, between the 22nd of June and the 23rd of September; during which period, though the Sun begins to decline, the heat continues to increase. The greatest heat,

according to observations made at Paris, is from the 13th of July, to the 7th of August: the middle of the natural summer is, therefore, about the 26th of July; but the middle of the astronomical summer, reckoning from the 22nd of June to the 23rd of September, is about the 7th of August.

The heat in summer is greater in the northern, than in the southern hemisphere; because the Sun is eight days longer on our side of the Equator, than on the southern side. Thus, there is an impenetrable ice in seventy degrees of latitude towards the South Pole, which we do not find in less than eighty degrees towards the North.

Although the winter is considered to commence from the 22nd of December, and to end on the 21st of March, we observe, at Paris, that the coldest season of the year is from the 25th of December to the 5th of February. Thus, the middle of actual winter is about the 15th of January; not on the 4th of February, as astronomers calculate. The seasons are, consequently, two or three weeks in advance of the solstices.

Astronomers reckon the longitude in the heavens along the ecliptic, beginning at the equinoctial point, or where the ecliptic cuts the equator in Aries. We say that the Sun is in the equinox, when he is in the equator, or when his altitude at Paris is forty-one degrees, or thirty-eight and a half at London; and the Sun's longitude*, at other times, may be reckoned by his distance north or south of the equator: for instance, when the Sun is advanced thirty degrees in the ecliptic, he is eleven degrees and a half from the equator. The longitude of the stars may be known by observing their distances from the Sun†; thus, when a star is more advanced than the Sun by thirty degrees, and that the Sun is twenty degrees from the equinoctial point, we are certain that the star is at fifty degrees, or that it has fifty degrees of longitude.

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* The Sun's longitude and his place in the ecliptic, are synonymous.

† Or by reckoning their distance on the ecliptic from the first point, Aries.

Hence astronomers have been enabled to make those catalogues, in which the position of more than 20,000 stars are described; and the situation of the planets, their revolutions, motions, and irregularities ascertained, which are the principal objects of inquiry among astronomers.

To know at what time a planet rises or sets, find its place for the given time in an ephemeris, and mark it on the celestial globe; then rectify the globe for the Sun, by bringing the point of the ecliptic in which he is situated for that day, to the meridian; set the index to twelve at noon, and bring the place of the planet to the eastern edge of the horizon, and the time of its rising will be seen on the hour-circle. Turn the globe westward, and when the planet is in the horizon, the index will show the time of its setting. By this method we may mark the geocentric situations of all the planets.

If the planet's place does not differ from that of the Sun more than fifteen or twenty degrees, it will scarcely be visible to the naked eye, which is always the case when a

planet is in conjunction with the Sun; that is, when it is in the same sign and degree of the ecliptic. This takes place with Saturn in a year and thirteen days; with Jupiter, every three hundred and ninety-nine days; with Mars, two years and fifty days; with Venus, five hundred and eighty-four days, or nineteen months; and with Mercury, one hundred and sixteen days, or nearly four months. These are the synodical revolutions of the planets, or their return to a conjunction with the Sun, which are the only remarkable ones to astronomers. Each planet, after the period of its synodical revolution, is seen again at the same distance from the Sun, and at the same hour, though not in the same season.

Thus, Venus reappears every nineteen months, with such remarkable brilliancy, that she is visible in full day to the naked eye.

CHAPTER THE FIFTH.

On the Moon.

HAVING considered the motion of the Sun, we will now proceed to that of the Moon, which will be found much less complicated, at least in its principal circumstances. This satellite changes its figure every month, making the circle of the heavens in a contrary direction to that of the general motion; and though she appears to rise and set every day, like the other heavenly bodies, from east to west, yet she constantly retrogrades, increasing her distance from them nearly thirteen degrees daily. This particular motion, by which the Moon retires progressively towards the east, even while she is advancing towards the west, is called her proper, or periodical motion; which is so considerable, that in the space of

twenty-seven days and eight hours, she may be observed near some remarkable star, which she will leave, retiring towards the east; and, making the whole circle of the heavens in an opposite direction to the common or diurnal motion, will return again to the same star whence she commenced her course. This space of time, in which the Moon completes her revolution round the Earth, is called a periodical month.

But when the Moon has actually made the circle of the heavens, and is returned to the same star, she is, nevertheless, not arrived at the same point in respect to the Sun; because, during the twenty-seven days, the Sun himself will have advanced nearly twenty-seven degrees towards the east, consequently, the Moon must travel over this additional space, before she arrives at the same point in respect to him, as at the beginning of the month. This return to the Sun is made in twenty-nine days, twelve hours, and forty-four minutes.

The return of the different phases or figures of the Moon, are completed in this interval of

time, which is called a lunar or synodical month.

The Moon appears full, when she is enlightened on the side towards us; that is to say, when she is directly opposite to the Sun, and the Earth is between them. But when the Moon is in her quadrature, or that the Sun, Moon, and the Earth form a right angle, though she still receives the same portion of light, we see only the half of that part which is enlightened, and that which is turned from the Sun is obscure, or invisible to us. She then appears as a half Moon. When she is in conjunction with the Sun, she is between him and the earth; his light is consequently reflected on the side which is turned from us, which renders her invisible. This is the case for some days at the time of the new Moon.

Having totally disappeared during three or four days, she is seen again towards the west, after sun-set, in the form of a crescent, the points of which always turn upwards, or in opposition to the Sun. This first appearance was the *neomania* of the ancients, which was celebrated in all nations by rejoicings. The Moon continuing

to advance towards the east, and increasing her distance from the Sun by her own motion, becomes larger and more luminous; her crescent increases; she continues longer visible; and when she is ninety degrees from the Sun, she appears as a bright semi-circle, or half Moon. She is then in her quadrature, which is called her first quarter. Seven or eight days afterwards, she appears full, round, and brilliant, rises when the Sun sets, and shines all night: she is then directly opposite to the Sun, and is called a full Moon.

After which, her light and size daily diminish; she rises later, and shines only during half the night, appearing again in the form of a semi-circle, the convex side turned towards the Sun, which is her last quarter. Some days afterwards, continuing to approach nearer to the Sun, she appears only as a crescent, and is seen in the morning, in the east, before the Sun rises, the points or horns turned towards the west; when she gradually diminishes in size and light, and at length being lost in the rays of the Sun, she totally disappears.

These different phases of the Moon, the full,

the first and second quarter, and the change, have served to divide the month into four equal parts, or weeks, each containing seven days; which division of time corresponds with that of the ancients, of almost every nation.

The Moon, therefore, making nearly twelve revolutions annually, naturally divided the year into twelve months; and, probably from respect to this number, the day and night were also divided into twelve hours. The number twelve affords, likewise, very convenient subdivisions. It has been celebrated in all countries, and in all religions. There were twelve principal deities in Egypt, twelve labours of Hercules, twelve tribes of Israel, and twelve apostles of Jesus Christ.

CHAPTER THE SIXTH.

On the Calendar.

THE Calendar contains one of the most curious applications of the motions of the Sun and Moon. In our common year there are three hundred and sixty-five days; but we calculate that the Sun's annual revolution is completed only in three hundred and sixty-five days and a quarter. From this difference of a quarter of a day, every fourth year ends a whole day before the solar year; in that year, therefore, we reckon three hundred and sixty-six days, which we call bissextile, or leap year, and the additional day is added to the month of February.

But the difference between the common and the solar year, does not amount to a quarter of a day, by eleven minutes, so that at the expiration of a hundred years, we should add nearly

a day too much. For this reason, the years 1700, 1800, and 1900, are common years, instead of bissextile, as they would be, reckoning every fourth year as such; but the year 2000 will be bissextile, because the error of eleven minutes, requires the suppression of only three bissextiles in four hundred years. This short explanation comprises all the rules of the solar year, according to the reformed Calendar in 1582. The years called bissextile, are those which may be divided by four, such as 84, 88, 92, &c.; even the centenary years 1600, 2000, 2400.

The explanation of the lunar year, according to the Calendar, will appear more complicated. In the *Bourgeois Gentilhomme,* M. Jourdain desires his master of philosophy to teach him the almanack. Moliere knew it was not an easy task, but we will simplify it as much as possible.

The lunar month, or the return of the phases of the Moon, is twenty-nine days, twelve hours, and forty-four minutes; twelve lunar months, therefore, do not complete a solar year by eleven days: but at the expiration of nineteen

years, there will have been two hundred and thirty-three lunar, and two hundred and twenty-eight solar months, which will be found to amount to the same thing, and the Moon commences again with the year.

The Golden Number is a series of nineteen numbers, corresponding to the nineteen years of the lunar cycle, and indicating the years which must elapse before the new Moon happens again on the 1st of January, as, for instance, in 1786. In that year the golden number was one; in 1787, two; in 1788, three; and so on successively. And every year, the new Moon happens eleven days sooner, which difference amounts, in three years, to thirty-three days, or a whole lunar month and four days; there are, consequently, thirteen new Moons in every third year.

The Moon which regulates Easter, is that which is full on the 21st of March, or the first full Moon afterwards; the Sunday following being always Easter Sunday, which may accordingly vary from the 22nd of March to the 25th of April.

The Epact is the number which indicates

the age of the Moon on the 1st of January: thus, when the Epact is one, as in 1778, the Moon is a day old when the year commences; that is to say, that there was a new Moon on the 31st of December.

The Epacts are always increased by eleven, that being the difference between the lunar and the solar year. Thus, in 1779, the epact was 12; in 1780, 23; and so on successively, except in 1786, when it increased by 12, which happens every nineteen years: that is, when the golden number has been nineteen, and becomes again one, the lunar cycle being completed. We may find the epact of any year by adding eleven, and subtracting thirty, when it amounts to that number. Thus, we shall find 9 for 1795; the following year 20, then 1, 12, 23, 4, 15, 26, 7, 18, &c.

The epact serves to find the age of the Moon, by adding it to the day of the month; but, from the difference between the Calendar and the lunar month, there would be an error in December of ten days, by this method of computation, because the Moon gains a day in

every month, except January and February, when that which is gained in the former month is lost in the latter, it being the shortest in the year. For this reason we reckon one day more for every month, beginning at the month of March.

To find the Moon's age, for instance, on the 16th of July, 1787, we add 16 to the epact of that year, which was 11, and five days more, because July is the fifth month from March. Thus, 16, 11, 5, are 32. Subtract 30, and the age of the Moon is 2. There was, in fact, a new Moon on the 14th, near midnight. It is, however, very possible, that there may be an error of a day, or even two, in this method of calculating; but we cannot expect a greater precision, in so simple a rule: to be more correct, we must have recourse to one much more complicated.

The solar Cycle recommences every twenty-eight years. The first year of each cycle, as in 1784, begins on a Thursday; the second on a Saturday, the first year being bissextile, or three hundred and sixty-six days, which are fifty-two weeks, and two days over; the third

on a Sunday; and so on successively, increasing one day after every common year, and two after each bissextile, hence called leap-year.

From this increase, or lapse of a day, the seven days of the week will each begin the year four times; that is to say, it will be twenty-eight years before the same order returns, as at the commencement of the cycle.

CHAPTER THE SEVENTH.

On Eclipses.

NO discovery in astronomy has excited more surprise, than the calculation of eclipses; probably from their being so striking a spectacle, as the difficulty is in fact no greater than in other calculations. A total eclipse of the Sun is, indeed, a most remarkable phenomenon. We pass, in an instant, from the brightest day, to an obscurity equal to the darkest night. Our horses stop in the middle of the road, not knowing where to place their feet; the dew begins to fall, from the sudden suspension of heat; and even the birds drop to the ground, terrified by such an unexpected and awful obscurity! There has been no total eclipse at Paris for a length of time, except that on the 22nd of May, 1724; nor will there be any other during the nineteenth century, which I

have ascertained, to satisfy the curiosity of Louis the Fifteenth. There will be only an annular eclipse in 1847, similar to those of 1748, and 1764, in which the diameter of the Sun exceeded that of the Moon, forming a circular ring of light all round her.

The course of the Moon's orbit in the heavens differs from that of the Sun, that is to say the ecliptic, by five degrees; but she crosses it in two points, which are called the Nodes. The Moon passes one of these nodes every fifteen days, and, if the Sun happen to be near the same point, she will hide the whole or a part of his disc, which will occasion an eclipse of the Sun; but if the Moon be in opposition to the Sun, she is hid by the Earth, which causes an eclipse of the Moon.

Thus, there must be an eclipse at least twice in the year: at the new or full Moon, when the Sun passes near one of the two points in the heavens, in which are the nodes. But those eclipses are not always visible to us, because the Moon can hide the Sun from only a part of the Earth. In 1786, we had no eclipse at Paris.

There may happen six or seven eclipses in the same year, in different parts of the earth, because an eclispse may take place when the Sun does not correspond exactly with the nodes of the Moon. These two luminaries may appear, from their great magnitude, to touch each other, when they are not exactly in the same point of the heavens; and the Moon may hide a portion of the Sun from some parts of the Earth, though she may be several degrees distant from her node, or the intersection of the two orbits.

Eclipses return nearly in the same order every eighteen years and ten days. This important and curious remark, which was made more than six hundred years before the vulgar era, enabled Thales, perhaps, to make his prediction to the Ionians, of a total eclipse of the Sun, which happened during the war between the Lydians and Medes. Some assert that this eclipse took place in the year 585, and others in 621, before Christ; but what Herodotus says of this prediction, is so vague, that it still remains doubtful whether it was ever actually made.

CHAPTER THE EIGHTH.

On the System of the World.

I HAVE hitherto spoken of the diurnal motion of the heavens, and of the annual revolution of the Sun. These, however, are both merely apparent, which I shall now explain on the system of Copernicus.

The motion of the Earth is difficult to conceive, by those who have imbibed the ancient prejudices; but astronomy furnishes us with such indubitable proofs of the fact, that the most eminent ancient philosophers have acknowledged its truth. Aristarchus of Samos, Nicetas, Philolaus, and other Pythagoreans, were sensible of the difficulty of imagining that the heavenly bodies revolved in twenty-four hours round the Earth; and the great Copernicus demonstrated the impossibility of such a system.

Indeed, when we behold, in the immense expanse of the heavens, the millions of stars, which are at so prodigious a distance from us, and observe that the planets all move in a contrary direction to the diurnal motion, it becomes impossible to conceive that these different globes revolve together in twenty-four hours, round such an atom as the Earth. It is not only an improbable, but I will venture to say an absurd supposition; and those only who are blinded by the most ignorant prejudices, will persevere in such an idea.

Can we suppose that the planets, whose motions are so different from each other; that the comets, which bear so little resemblance to the other celestial bodies; or that the millions of fixed stars, which we see through our telescope in every part of the heavens, having no connexion with each other, and being at such immense distances as the imagination can scarcely conceive?—can we, I say, suppose that all these unite together, as if one body, to revolve daily round an axis which itself changes its position? This regularity in the motion of so many bodies, so irregular in

every other respect, ought to be a sufficient indication to philosophers, that there is nothing real in these appearances, while it proves the motion of the Earth beyond the possibility of doubt.

Since we have been enabled by the aid of telescopes, to perceive, without the slightest degree of uncertainty, that the Sun, Saturn, Jupiter, and Mars, revolve daily on their axes, it becomes still more impossible to doubt the rotation of the Earth round hers.

These reasons are simple, and appear incontrovertible. If all the celestial bodies moved daily together, they must be by some means united; but it is evident that they have no connexion, as they have all different periods, consequently, their general daily motion round the Earth is impossible.

When we are satisfied of the motion of the Earth, it will not be difficult to conceive its annual revolution round the Sun; because a body cannot revolve round its own axis, without advancing at the same time; as we see the planets Jupiter and Mars turning on their axes, while they advance in their orbits.

We have a remarkable indication of the annual motion of the Earth, in the retrograde motion of the planets every year, as soon as they are in opposition to the Sun; when, instead of continuing their course from west to east, according to the order of the signs, and the natural direction of all the celestial bodies, they stop and return again, retiring towards the west. This retrograde motion, is from six to seven degrees for Saturn, ten for Jupiter, and even nineteen for Mars. Copernicus readily perceived, that this was the natural effect of the motion of the Earth, which, in passing between the Sun and the planets, and moving faster than they towards the east, leaves them behind her, that is, towards the west; so that they appear to move in an opposite direction to us, though they are, in fact, pursuing the same course.

We see, evidently, that Venus and Mercury circulate round the Sun; because they are always near him, though their distance from him appears to increase and diminish alternately, being much larger when on this side of the Sun, than when beyond him.

The discovery of telescopes, in 1610, rendered this phenomenon still more evident by the phases of Venus, she being round and full when beyond the Sun, and appearing as a crescent when nearer to us than the Sun, and on the side of him. Sometimes she passes over the Sun's disc like a black spot, as in 1761, and 1769.

All these different appearances clearly indicate that Venus revolves round the Sun. This is likewise the case with Mercury, who has been observed to pass eighteen times over the Sun's disc, and will again in 1815 and 1832.

Thus, the motion of the planets round the Sun, greatly simplifies the explanation of their inequalities, and naturally leads to the admission of that of the Earth. Fontenelle, in treating of the system of Copernicus, in his *Dialogues on the Plurality of Worlds*, says: "The Marchioness, whose discernment is quick and penetrating, conceived that there was a degree of affectation, in exempting the Earth from a law to which so many other large

bodies were subject; and that the Sun was by no means so well calculated to revolve round the Earth. In short, it was determined that we should adopt the system of Copernicus, as being more consistent, and devoid of prejudice: indeed, its simplicity persuades, while its boldness pleases."

But the system of Ptolemy, which prevailed so long in the schools, appeared still more simple, because he supposed the Earth to be immovable in the centre of the universe, making the planets, and the Sun himself, revolve round it. But the ignorance and superstition of that age, could alone have induced a belief in this system, rendered absurd by the enormous complication of those motions, which must be admitted, to explain these different phenomena, and which the motion of the Earth renders the most simple imaginable.

It appears surprising, that one of the principal obstacles to the Copernican system should have proceeded from that passage in Scripture, in which it is said that Joshua desired the Sun to stand still. To suppose that Joshua spoke

in philosophical language, unknown both in his country and in his time, would be to exclude from the Bible all those expressions which are used in society, and which no one pretends to misunderstand. Astronomers, as well as others, say, that the Sun rises and sets, and will continue to say so to all eternity, without attempting to deny the real state of nature, and the immobility of the Sun. It would be folly to suppose that the general of an army, such as Joshua, at a moment when he was anxious to manifest the majesty and power of God to his soldiers by a great victory, should have thought proper to give them a lecture on astronomy, and, quitting the language his soldiers understood, desire the Earth to stand still; he must, at the same time, have entered into an explanation of this singular expression, and certainly no digression could ever have been more misplaced. Therefore, even supposing that Joshua spoke as a prophet, and had been instructed by the power of God, in things of which others were ignorant in his time, and particularly in his country, he could

not have expressed himself otherwise than he did.

The system of Tycho Brahé, was conceived merely to obviate this difficulty. This religious, or timid author, being compelled to admit the motion of the planets round the Sun, which Copernicus had so clearly demonstrated, conceived it possible to suppose, from respect to the Scriptures, that the Sun, accompanied by all the planets, moved round the Earth. It is true, that, by this means, all the phenomena of the heavens were easily explained; as a child who found himself, for the first time, in a passage-boat at St. Cloud, would describe all he saw, by saying that the villages of Chaillot and Passy were going to Paris, and that the boat stood still.

The most common objection to the motion of the Earth, is, that the birds in the air would be left behind; and that a cannon ball, shot perpendicularly, would not fall again near the same spot, which would be carried to so great a distance, by the motion of the Earth, while the ball was in the air: but this reason-

ing is erroneous. It is impossible to suppose, that terrestrial bodies, and the atmosphere of the Earth, which have been for so many ages united, should not have received one common motion—one general impulse and direction. It is surprising that Tycho Brahé, P. Riccioli, and all those who have repeated the same arguments, under so many different forms, should not have known, that a stone thrown from the mast-head of a vessel under sail, would fall again precisely at the foot of the mast, as if she were immovable. It would appear, to those on shore, to describe an oblique line, or the diagonal of the two motions; that of the vessel being previously communicated to the mast, the stone, and every thing connected with it, they all act together, as if one body. It is by the shock only of foreign objects, not moving in the same direction as ourselves, that we perceive the motion of the vessel. But the Earth meets with no such obstacle: there is absosolutely nothing in nature, which can, by its resistance, make us sensible of its motion. This

impulse is common to all terrestrial bodies: if they ascend into the air, they previously receive their direction and velocity from the motion of the Earth; and, were they even to rise to the utmost boundary of our atmosphere, their motion would still be in conformity with it.

In the *Cabinets de Physique,* there is a small machine, resembling a cart, which, while moving, throws up a ball in the air, and receives it again in the same shell, into which it always falls, though the machine, in the interval, removes to some distance. A cannon ball, fired quite perpendicularly towards the zenith, would fall again into the cannon's mouth, though, while the ball was in the air, the cannon would be carried, by the motion of the Earth, many miles towards the east, (about six leagues and a quarter in a minute, under the equator.) The reason of this is evident: the ball, in rising into the air, loses nothing of the velocity communicated to it by the Earth, these two impulses being by no means incompatible. A ball may ascend a league in the

air, and, at the same time, advance six leagues towards the east: its motion, in absolute space, is the diagonal of a parallelogram, one side of which is one league, and the other six. It falls again by its natural weight, describing another diagonal, to the mouth of the cannon; which, together with the ball, will have continued in a direct line from the centre of the Earth, to the summit of that whence it was shot.

This, however, is a very difficult experiment: Father Marsenne and Mr. Petit attempted it in the last century, but they did not recover their ball. At Strasburg it was found, at the distance of three hundred and sixty-seven toises; but it would have fallen several leagues off, had it not been affected by the motion of the Earth.

As the planets all revolve round the Sun, it is from thence we must suppose their situations, and the laws of their motions to be observed; but there are times when the Earth is so placed, that every thing appears to us as if we were in the centre of the Sun: when a

planet, for instance, is on a line with the Sun and the Earth, whether the Earth be between them and the planet in opposition, or whether it be on the same side, or in conjunction with the Sun, the planet will appear to us in the same situation as if we saw it from the Sun.

It is by availing ourselves of these circumstances, that we have been enabled to ascertain the laws of motion of all the planets. Kepler discovered that the planets do not describe circles, but ovals or ellipses, round the Sun. That they actually move with more velocity, in proportion as they are nearer to the Sun; and that those planets which are most distant from him, are longer, in a proportion which he was the first to discover, in performing their revolutions.

This calculation appears rather complicated, as the distance must be multiplied twice by itself; and the time, or duration of its revolution, once by itself. The same rule applies to all the planets. The squares of the times are equal to the cubes of their distances,

Jupiter is five times further from the Sun than the Earth; and he is eleven times longer in making his revolution: the number 11, multiplied by itself, is 121; and the distance 5, multiplied twice by 5, is 125; which product is nearly the same. It would be perfectly correct, if calculated with more exactness.

By observations with respect to the Sun, astronomers have likewise determined the periods and inequalities of the planets, and have composed those tables used in the Ephemeris, to find the place of each planet for every day in the year.

The motion of the Earth round the Sun, and the immobility of that luminary with respect to us, does not render it impossible, that the whole of our solar system may be subject to some change of place; indeed, it appears probable that the stars are in continual motion, as they experience an attraction from so great a distance. We call them fixed stars, because their motion is invisible to us; but there are some few in which it has been observable, particularly Arcturus. In respect to the Sun, it

has been already explained, that a rotary motion, such as we perceive in that luminary, is inseparable from a motion of translation, or real change of place, in which he would be accompanied by the whole system—the Earth, the planets, and comets; but with what velocity, or in what direction, has not yet been ascertained; and the Sun must, at all events, be considered as without motion in respect to us, which has been already shown.

CHAPTER THE NINTH.

On the Attraction, or Gravitation, of the celestial Bodies.

THE gravitation which we experience on the Earth, by which all objects are impelled towards it, is so common a phenomenon, that it excites but little observation. If we consider it more attentively, we shall find that this principle is universal.

The Earth is round, and this gravitation, or attraction, prevails in every part of it. The inhabitants of New Zealand, who are diametrically opposite to us, are equally impelled towards it, though their feet are in direct opposition to ours.

It is difficult to conceive how men can inhabit countries which are antipodes, and where their feet are placed, as it were, against each other's. It would, at first, appear that the

heels of one of them must be above his head; that is to say, that he would be placed in an inverse position, and contrary to the order of nature. But, to correct our ideas on this subject, we have only to examine, why we stand upright on the surface of the Earth? and what it is which continually brings us again to the same situation, if, by any means, we are removed from it. This tendency of all bodies towards the Earth, whether we call it weight, gravitation, or attraction, and though its cause be unknown to us, is manifested in every part of the globe. Heavy bodies, in every direction, tend, by a constant and invariable influence, towards the centre of the Earth. Those bodies which fall towards it are every where considered to descend, and those which quit it to ascend. Thus, as iron is attracted by the load-stone, whether it be placed above or below it; so the Earth attracts on all sides, and with equal force, every object which touches or approaches it, without any distinction of place. That which we call above and below, is only so relatively to us, and to our manner of perception. Where we place our

feet, we call below; consequently, those who are at our antipodes, having their feet opposite to ours, call that part of the heavens below, which we call above.

This gravitation, which we experience on the Earth, because we are attracted by a large assemblage or mass of matter, extends equally to all the other planets, of which their globular figure furnishes indubitable proof. This form is the natural effect of gravity in every part: the Earth became round at the instant of its formation, as did the sea by which it is encircled; because all its parts tend towards one common centre, round which they are so disposed as to find their proper equilibrium: (with the exception, however, of a little flattening towards the poles, produced by the centrifugal force.) This equilibrium could not exist, if one part of the ocean were more distant from the centre of the Earth than another; therefore, equal gravity in every part of a body towards the centre, necessarily produces a globular figure. Anaxagoras, Democritus, and Epicurus, admitted this general tendency of all matter, whether on the Earth, or elsewhere;

and Plutarch speaks of it very clearly, in his work, *On the Cessation of Oracles*, in which he demonstrates that each world has its particular centre, its earth, and seas, and the necessary force to assemble and retain them round it.

On the other hand, it may be asked, Why the stars do not fall? by what means they are suspended? how it happens that the Sun is not impelled towards us, as well as terrestrial bodies? and what it is which retains the Earth in its place? To solve these difficulties, we must accustom ourselves betimes to this philosophical principle: That a body at rest cannot put itself in motion. The stars are not suspended, nor do they require to be so, because there is nothing to displace them: where they once are, there they will always remain. Those things only require support, which have a tendency to fall towards some point: but the stars have no such tendency towards the Earth; their distance from it is so great, that, if there be a reciprocal attraction, they can scarcely be affected by it.

It was Kepler who best explained, in 1609,

the universality of attraction; but it is to Newton we owe its final proof, and that which is still more important, its laws and measurement. Pemberton, his friend and companion, thus speaks of it, in the preface to his *View of Sir Isaac Newton's Philosophy:* "The first thoughts which gave rise to his *Principia,* he had when he retired from Cambridge, in 1666, on account of the plague. As he sat alone in a garden, he fell into a speculation on the power of gravity: that, as this power is not found sensibly diminished at the remotest distance from the centre of the earth to which we can rise, neither on the tops of the loftiest buildings, nor even on the summits of the highest mountains; it appeared to him reasonable to conclude, that this power must extend much further than was usually thought: why not as high as the Moon? said he to himself. And if so, her motion must be influenced by it: perhaps she is retained in her orbit thereby. Though the force of gravity may not be sensibly weakened by a trifling change of place, such as we experience in our atmosphere, it is

very possible, that, at the distance at which the Moon is from us, this force may be greatly diminished. To calculate what might be the quantity of this diminution, Newton conceived, that if the Moon were retained in her orbit by the force of gravity, there could be no doubt, that the principal planets turned round the Sun by virtue of the same power."

It is a known principle, acknowledged even in ancient times by Anaxagoras, that a body in motion continues to move in a right line, if it meet with no obstacle; and that a body moving circularly, flies off in a tangent, as soon as it escapes from that restraint which occasioned its circular motion. This may be clearly demonstrated by whirling a stone in a sling, which will fly off in a right line as soon as we let it go; or it may be rendered still more evident by the stone of a razor-grinder, as a drop of water thrown on it while turning, will instantly fly off in a straight line.

This would likewise be the case with the planets, if they were not retained by that central force or attraction which prevents their

escape, confining them, like the stone in the sling, to their circles or orbits.

Thus, the motion of the Moon round us, indicates the attractive power of the Earth; as the planets do that of the Sun, by turning round him. The satellites which circulate round Jupiter and Saturn, and always accompany them in their revolutions, prove a similar influence in those planets; it is, therefore, evident, that this attractive force exists every where, and that it is the general property of all matter. Hence, Newton compared the attractive power of the Earth on our bodies, with that which retains the Moon in her orbit, or which prevents her escaping by the centrifugal force, and flying off in a right line.

Terrestrial bodies descend towards the Earth with a velocity equal to sixteen feet in a second, as Galileo demonstrated, at the beginning of the seventeenth century; but the Moon, in her orbit, describes only a curve of the 240th part of a foot in the same interval of time, that is to say, 3600 times less. Now the Moon is sixty times further from the centre of the Earth than we are; and 3600,

or 60 times 60, is the square of 60. Therefore, the same force, which we will suppose diminishes in proportion as the square of the distance increases, will suffice equally to explain the descent of heavy bodies towards the Earth, and the time in which the Moon performs her revolution round it. It may be seen that this force diminishes more than the distance increases. At a distance ten times greater, the attraction is one hundred times less, because 10 times 10 are 100; which is to be understood when we say, *the attraction is in a proportion inverse to the square of the distance.* Such is the great law of attraction; which is verified and observable in all the celestial as well as terrestrial bodies. It may even be discovered in mountains, which, in proportion to their size, compared with that of the Earth, have an equal force to turn bodies from their perpendicular direction. Bouguer made the experiment in 1738, near a very high mountain in Peru, which might produce the two millionth part of the attraction of the Earth; and he perceived this power very sensibly.

The attraction of each of the planets on all

bodies within their influence, has furnished us with the means of ascertaining even their density, which appears, at first, very extraordinary, and much beyond the power of the human mind to calculate; but the following explanation will give some idea of the method by which we have been enabled to arrive at these conclusions.

The Moon which revolves round the Earth, and the first of the satellites which turns round Jupiter, are nearly at the same distance from their respective planets. If they moved with equal velocity, they would require the same attractive force to retain them in their orbits; and we should conclude that Jupiter possessed this power in the same degree as the Earth, and that he was composed of an equal mass of matter; but the satellite moves sixteen times faster than our Moon, which velocity produces sixteen times more force to escape from its orbit. Experience proves, that a body which moves four times faster, has sixteen times more force. It is the square of the motion, or 4 times 4, by which the force is measured:

now 16 times 16 are 256, consequently, Jupiter is 256 times more powerful and massive than the Earth. But he is 1000 times larger, therefore his force is not in proportion to his size; which can proceed only from his being of a substance four times lighter and less dense than that of the Earth, as stone is four times lighter than copper. The Sun and Jupiter have only the density of stone, that of the Earth is between marble and iron, and the density of Saturn is only equal to deal.

CHAPTER THE TENTH.

On the Method of measuring the Distances of the Planets from the Earth.

FEW things excite more astonishment in the minds of those who are not conversant with the science of astronomy, than the knowledge of the distances of the planets. It appears surprising that we should be enabled to assert, that the Moon is 84,000 leagues from the Earth; but it ceases to be so, when some idea is acquired of the manner in which this calculation is made.

To ascertain the distance of a planet, we have only to observe its appearance from different parts of the earth; as, the nearer an object is to us, the more it will seem to change its position, when seen from different points of view. If we ascend, objects appear to descend: from the gardens of the Thuilleries, the trees

seem much higher than when seen from the top of the building, because the visual ray inclines or descends, in proportion as the eye is more elevated, which difference, when applied to the heavenly bodies, is called the parallax, or change.

This term may appear rather scientific, but it is, nevertheless, very convenient, and expresses a very simple and familiar effect. If we were placed, at the play, behind a lady whose hat was so high as to prevent our seeing the stage, we should turn to the right or left, rise or sit, till we obtained a sight of it. This is a parallax, or a diversity of aspect, by virtue of which the hat appears to correspond with another part of the theatre, rather than the stage.

Thus, an eclipse of the Sun may happen in Africa, when there is none at Paris: we see the Sun distinctly, because we are so much elevated, that the Moon cannot intercept our view of him.

If two persons were making observations on the Moon at the same time, and placed diametrically opposite to each other on the earth,

that is to say, at each other's antipodes, on comparing their observations together, they would find that the Moon appeared more elevated by two degrees to one, than to the other; provided they had chosen the same star to determine her situation.

Thus we find, from observation, that the diameter of the Earth produces an angle of two degrees at the distance of the Moon; that is to say, that the visual rays of the two observers would be inclined towards each other two degrees. To ascertain the distance of the Moon by this observation, we have only to draw an angle of two degrees, that is, two lines, which will make between them an angle of two degrees; we shall find that the separation of these two lines will every where be the twenty-ninth part of their length, or nearly so; whence it follows, that the two visual rays, which, from the two extremities of the Earth, produce an angle of two degrees at the Moon, are twenty-nine times longer than their opening, which is the diameter of the Earth. This diameter, which is 2900 leagues, being multi-

plied by 29, the distance of the Moon from the Earth would be about 84,000 leagues.

But the parallax may be found even without a change of place, by carefully observing a planet which is near a fixed star, at the time of its rising and setting. To understand this properly, it must be observed, that the parallax which always lowers the planet, produces, however, a different effect in the east, from what it does in the west. In the east, the parallax makes the planet appear more to the eastward than the star, and in the west, more westerly; therefore, the planet will seem to leave the star in two opposite directions. If we remark this difference in its rising and setting, in the same night, with great attention, we shall discover the quantity of the parallax, as well as if our observations were made in two different countries; and the distance of a planet may be ascertained by the same means.

The transit of Venus over the Sun, in 1761, and 1769, has furnished us with the means of determining exactly the distance of the Sun from the Earth; many long journeys having been undertaken, to observe it at the same

time in different parts of the world. Two persons, at two thousand leagues distance from each other, viewing the transit of Venus, would see it by different rays, or in different directions, consequently, not on the same point of the Sun's disc; and she would appear to one, to quit the Sun sooner, by more than a quarter of an hour, than to the other. This difference being correctly observed, has enabled us to determine in what manner these rays, which extend from the two extremities of the Earth to the Sun, cross each other, consequently, what is the Sun's distance; because the angle is greater, in proportion as the summit is nearer, which we have already explained. We judge of the distance of objects, either in the heavens or on the earth, by the effect or change which is produced between two observations made from different points of view.

Nothing certain can be said as to the distance of the stars, which is so immense, that it would be impossible to discover any parallax; there is nothing which we can compare to them, and it is only by comparison that any

measurement can be obtained. The only circumstance of which we could avail ourselves, would be the orbit which the Earth describes in the course of a year; but though this is sixty-eight millions of leagues, we see the stars in the same manner, and in the same direction, while the Earth moves from one extremity to the other of this immense orbit. If there were a difference of even a single second, which is only the two hundred thousandth part of the distance, we should perceive it by observations made every six months; but it appears that there is not even this trifling difference, consequently, the stars must be at least four hundred thousand times further from us than the Sun, or more than fourteen millions of millions of leagues from the Earth.

When we know the distance of a planet, and the angle under which it appears to us, it is easy to ascertain its diameter. If, for instance, the Moon appear to us to be half a degree, it is the hundred and fourteenth part of the radius of a circle; she must, therefore, be a hundred and fourteen times less than her

distance from the Earth, which being eighty-four thousand leagues, the diameter of the Moon would, consequently, be about seven hundred and thirty-six leagues. The result of these calculations may be seen in the following table.

I have only marked the smallest distances of the planets, as they vary in respect to us; to which I have added the duration of their revolutions, in days and years, and the diameter of each planet, in leagues of 2280 toises, or three geographical miles, seventy-five to a degree.

The smallest distance from the Earth.			Diameter in leagues.	Revolutions.	
				Years.	Days.
Moon,	84,000	leagues	736		27
Sun,	34,000,000	ditto	319,300		365
Mercury,	21,000,000	ditto	1,166		88
Venus,	10,000,000	ditto	2,748		225
Mars,	18,000,000	ditto	1,490	1	321
Jupiter,	144,000,000	ditto	31,118	11	315
Saturn,	293,000,000	ditto	28,601	29	161
Herschel,	621,000,000	ditto	12,700	18	294

There are three methods of calculating the revolution of Mercury and Venus.

CHAPTER THE ELEVENTH.

On the Refraction of the Stars.

ASTRONOMICAL refraction is another phenomenon, to which astronomers pay particular attention, and of which they make frequent use. This refraction is the oblique direction of the rays of light falling from the heavenly bodies towards us, which being bent, or turned from their first course, half a degree in the horizon, by the density of the atmosphere, reach the eye sooner than they would if there were no refraction; hence, we every day see the Sun rise three or four minutes before he is actually risen.

If we place a crown-piece in the bottom of a basin, and retire to a short distance, so as just to lose sight of it, if the basin be gently filled with water by another person, the crown, from the effects of refraction, will gradually

appear to rise, and when the basin is full, we shall see it distinctly.

The twilight is likewise another effect of the atmosphere, which reflects and disperses the light, procuring us a mild and gradual transition from light to darkness, and from night to day. The dawn of the morning begins, and the evening twilight ends, when the Sun is eighteen degrees below the horizon; so that at Paris, in the summer, the twilight continues all night, because the Sun does not descend eighteen degrees below the horizon, even at midnight. Those who live under the Pole have a twilight of seven weeks, by which the duration of their night is shortened fourteen weeks; and, during that time, the Sun never appears above the horizon.

The duration of twilight depends upon the time which the Sun takes to rise or descend eighteen degrees, which is at least an hour and twelve minutes, and generally more. Till the twilight ends, the smallest stars are invisible to us; but we begin to perceive those of the first magnitude when the Sun is only ten degrees below the horizon, and Venus may be seen

much sooner: she is even sometimes visible before sun-set.

The height of the atmosphere is fifteen leagues, and the light of the Sun is 1354 times less in the horizon than in the meridian.

CHAPTER THE TWELFTH.

Of the Satellites of Jupiter, Saturn, &c.

THE satellites of Jupiter are four small planets which circulate round him, as the Moon does round the Earth, and accompany him round the Sun. They were discovered by Galileo, in 1610, with his improved telescope. They are sometimes seen before, and sometimes after Jupiter; and when they enter the shadow which he casts behind him, they are eclipsed, as our Moon is when the light of the Sun is intercepted by the Earth. Astronomers frequently avail themselves of these eclipses, to determine the longitude.

The great progress that has been made in geography during the last century, is principally owing to the assistance derived from the first satellite of Jupiter, which being eclipsed every two days, furnishes continual opportunities to travellers to ascertain the longitude; and the latitude of a place being known by the altitude

of the Sun, or that of the stars, we are enabled to mark it on a map or globe, so as to find it again with certainty. This was the object of those voyages round the world, which have been undertaken, particularly of late years, by Captain Cook, Bougainville, La Perouse, and many others.

Saturn has also seven satellites which circulate round him. The fifth was discovered by Huygens, in 1655; the first, second, third, and fourth, by Cassini, in 1671; and the sixth and seventh by Doctor Herschel, in 1789; but they are so small, that they can be seen only with very superior telescopes.

The periods of their revolutions will be found in the following table.

REVOLUTIONS OF THE SATELLITES

Of Jupiter.			Of Saturn.			
Satellites.	Days.	Hours.	Satel.	Days.	Hours.	
I.	1	18	I.	1	21	
II.	3	13	II.	2	18	
III.	7	4	III.	4	12	
IV.	16	16½	IV.	15	23	
			V.	79	8	
			VI.	1	9	Discovered by Dr. Herschel.
			VII.		23	

CHAPTER THE THIRTEENTH.

Of Comets.

COMETS were, for a length of time, an object of terror, either from the unfrequency of their appearance, or from their extraordinary figure, which is, indeed, often alarming; but in the present day they are considered only as planets, which revolve round the Sun, and whose return may be predicted with certainty. This was verified by the comet of 1759, which had before appeared in 1682, its return having been predicted by Halley, in 1705.

The irregularity in the motions of comets is merely apparent, they being governed by the same laws, in respect to the Sun, as the planets; with this difference, however, that the orbits of the planets are nearly round, and those of the comets are very long ovals, by

which means they are carried far beyond our sight, and are, for a length of time, invisible to us. Moreover, comets are seen in all directions. That of 1769, which was one of the nearest to the Sun, and the one most generally known, is sixty-one times further from the Sun in its aphelion, than in its perihelion; and is nearly seventy-six years in making its revolution, though it is visible to us only six or seven months.

Comets may be distinguished by their motion, from the new stars of which we have before spoken, as in these, no motion has ever been observed; besides which, the light of a comet is always soft and feeble, being reflected from the Sun only towards us, as is the case with the planets. But they may be principally distinguished by that train of light with which they are generally accompanied, called the coma, or tail; though there have been comets without these. That of 1585, observed during a month by Tycho Brahé, was rounded, without any such appearance, except that its circumference was less luminous than the nucleus. The comet of 1665 was very

clear, and had little or no tail; and that of 1682, according to Cassini, was as round and clear as Jupiter. These tails, therefore, cannot be considered as entirely characteristic of a comet.

No less than five hundred comets have been mentioned by different authors; but there are only ninety-four which have been observed and described, up to the year 1805, sufficiently to be known when they reappear.

It has frequently happened that several comets have been seen at the same time; and since the year 1758, that they have become an object of particular attention to astronomers, numbers have been discovered, which would have been unobserved without the assistance of telescopes. Of these, the greatest number have been discovered by Mechain, Bouvarde, and Miss Herschel.

Those comets which have continued the longest visible, have appeared only during six months. The first of these was in the time of Nero, in the year 64 of our era; the second about the year 603, in the time of Mahomet;

and the third in 1240, during the irruption of the great Tamerlane.

The comet of 1729 was visible for six months, from the 31st of July, 1729, to the 21st of January, 1730; and that of 1769, almost four months.

All comets appear, from the effects of the diurnal motion, to revolve, like the other heavenly bodies, round the Earth; but they have a motion of their own, similar to that of the planets, by which they correspond successively to different fixed stars. This motion is sometimes towards the east; sometimes towards the west; sometimes along the ecliptic; and at others in a quite different direction, and perpendicular to it.

The motion of the comet in 1472, was one hundred and twenty degrees in one day, having retrograded from the extremity of the sign of the Virgin, up to the beginning of that of the Twins; and the comet of 1760, between the 7th and 8th of January, changed its longitude forty-one degrees.

The ancients seldom spoke of the size of comets, without including their coma; yet there

have been some whose diameter appears to have been very considerable, independent of that circumstance. After the death of Demetrius, king of Syria, 146 years before our era, there was a comet as large as the Sun; and that which appeared at the birth of Mithridates, reflected, according to Justin, even more light than the Sun.

The comet of 1006, was four times larger than Venus, and reflected as much light as the Moon in her quadrature. This comet appears to be the same as that of 1682, and 1759. The comet of 1744, which was the most remarkable that has appeared during the last century, was not of a particularly large diameter; but its coma was of an extreme length and brilliancy. It excited so general a sensation, that even the ladies dressed their heads *à la comète;* and it is still spoken of as a most remarkable phenomenon. The comet of 1769, had also a tail ninety-seven degrees in length, but it was not very luminous.

There have been philosophers in all ages, who considered comets to be no other than

planets, whose motions and revolutions were perpetual and regular, which opinion has been attributed to the ancient Chaldeans. It was, at least, that of Pythagoras and several others, such as Diogenes, Favorinus, and Democritus, who, in the opinion of Cicero and Seneca, was the most subtle of all the ancient philosophers.

Seneca, in his *Natural Questions*, speaks very philosophically on the subject of comets, and concludes by this very remarkable prediction: "Hereafter," he says, "posterity will wonder, that things so evident in themselves should have escaped us: it will be demonstrated into what regions the comets wander; why they go so far beyond the other planets; and what is their number and diameter."

Notwithstanding these enlightened ideas on the nature of comets, there were many authors, among the ancients and moderns, up to the beginning of the last century, who believed that comets were bodies newly formed, and of a temporary existence. Of this number were Aristotle, Ptolemy, Bacon, Galileo, Tycho Brahé, Kepler, Riccioli, and La Hue. Many

of these considered them as sublunary bodies, or atmospheric meteors; and Cassini himself believed that comets were formed by exhalation from the other stars. This was, likewise, the opinion of Aristotle, and consequently was that which prevailed in the schools up to the last century; till which period the generality of astronomers, considering comets as merely a collection of vapours, conceived them unworthy of particular attention.

Tycho Brahé, however, having carefully observed, for a length of time, the comet in 1577, composed a considerable work on that occasion. He found that these appearances might be reasonably accounted for, by supposing that they described a portion of a circle round the Sun; demonstrating in that work, that comets were bodies which moved in regions far above that of the Moon, thus destroying the ancient system of the solidity of the heavens.

Dominic Cassini conceived that comets revolved round the Earth; Fontenelle, that they were planets of another system; and

Hevelius imagined that they described parabolas round the Sun; but Newton, having discovered that all the planets revolved round that luminary, by virtue of a powerful and extensive attraction, conceived that this must likewise be the case with comets, and having made the experiment on that of 1681, he found that its motion, which had appeared very irregular, was perfectly consistent with an oval curve, similar to that of the planets, and directed by the same laws.

The principal irregularities observable in its motion, and which had induced some astronomers to believe that there were two different comets, then appeared to be the natural consequence of the situation of the Earth in respect to the comet, and of the acceleration necessarily produced in the motion of a planet, on its approach towards the Sun.

Upon this theory, Halley calculated all the comets which had been observed up to that time, with sufficient exactness to determine their orbits. He conceived that those of 1531, 1607, and 1682, bore a sufficient resemblance to each other, to be supposed one

and the same comet, and that it might probably reappear in 1758, or 1759. This fortunate conjecture, published in 1705, was verified by the return of the same comet, and in the same orbit; which, having been visible to every one, leaves no doubt that comets are really planets, which revolve, like the other planets, round the Sun. It made its first appearance on the 25th of December, 1758, and continued visible till the 3rd of June, 1759.

This comet is the only one whose return is certain; the others may, perhaps, never reappear.

CHAPTER THE FOURTEENTH.

On the Figure of the Planets.

WHEN we observe the Moon through a telescope, we perceive, very distinctly, some luminous points, which appear at a distance from the enlightened part, and which being consequently more elevated, receive the light of the Sun before the rest. These are undoubtedly the tops of mountains, and we may even judge of the degree of their elevation, by their distance from the other light parts. Some of these have been ascertained to be a league in height; much higher, in proportion, than those on the Earth, which, though four times larger than the Moon, has no mountains exceeding 3217 toises, not a league and a half in perpendicular height.

These different mountains in the Moon, irregularly dispersed over its surface, appear

to the naked eye like the features of a face; but, on a closer inspection, or when seen through a telescope, we do not find the slightest resemblance.

The Sun is likewise said to have the form of a face, though with as little foundation. Sometimes he is represented as interspersed with foaming volcanoes, but in reality we see only a smooth and yellow surface, upon which some dark spots occasionally appear, which we call maculæ; perhaps the scum or schoria of this immense furnace, or more probably the nucleus, or solid body of the Sun, covered by a stratum of fluid matter, of no great depth, which sometimes leaves its eminences and the points of its mountains uncovered.

These spots were discovered by Galileo, in 1611, on the first application of telescopes to celestial objects. Some of them are sufficiently large to be distinguished with the naked eye; though the Sun should always be viewed through smoked glass, as a necessary precaution to preserve the sight. It is by means of these spots, that the Sun has been ascertained

to turn on his axis in twenty-five days and a half.

These maculæ have sometimes been observed on the Sun's disc during several months, continuing to turn with him; but in general they change their figure, and totally disappear before the Sun has made one revolution. The motion of the Sun round his axis, necessarily indicates a motion of translation, or change of place, in which, as we have before observed, he is accompanied by all the planets which circulate round him.

There are several light belts on the surface of Jupiter, which are subject to different changes, supposed, by some philosophers, to be seas, extending all round his equator, and consequently in the direction of his rotation. We also distinguish some small lucid points on his surface, which indicate his motion round his axis. This motion is considerably more rapid than that of the Earth, it being completed in less than ten hours; which producing, in this planet, a much greater centrifugal force than that of the Earth, he is consequently more flattened towards the poles.

There are some spots likewise visible in the planet Mars; but they are much less distinct, though sufficiently so to satisfy us, that he turns round his axis once in twenty-four hours and thirty-nine minutes. Saturn completes his rotation in ten hours and a quarter.

There are no spots in Mercury and Venus, by which their motion may be distinguished; but Cassini conceived the time of the rotation of Venus round her axis, to be twenty-four hours; and Mr. Shroter has since determined it to be twenty-three hours, twenty minutes, and fifty-nine seconds, which is nearly the same. According to this celebrated astronomer, the rotation of Mercury round his axis is made in twenty-four hours, five minutes, and thirty seconds.

Saturn's ring, the most extraordinary phenomenon that has been discovered since the introduction of telescopes, is a large thin crown, which encircles, without touching this planet. From the oblique manner in which it is seen by us, it appears in an oval form, though it is, in fact, perfectly round. It may be compared to a cardinal's hat, or a

basin, in the middle of which is a very large ball. As this ring is extremely thin, it is not visible when its edge is presented to us, and the planet then appears round. This happens every fifteen years, when Saturn is in the two parts of his orbit where the plane of the ring points directly towards us; as in 1804, and as it will be in 1819. This ring is 67,000 leagues in diameter, between which and the planet, there is an interval of 9500 leagues; and its breadth in every part is as much more. It appears difficult to conceive how this immense arch is suspended in the heavens; but as all its parts are united, and gravitate equally towards the planet, they mutually support each other; each part being retained by the general pressure within its proper limits: besides which, its revolution on its axis is sufficient to sustain it in the air.

An achromatic telescope of thirty-two inches focus, with an aperture of two inches, which will magnify seventy or eighty times, will show us all the most remarkable appearances in the heavens: the mountains in the Moon,

with their shadows reflected to a considerable distance; the satellites of Jupiter, with his belts; the phases of Venus; the maculæ, or spots in the Sun; Saturn's ring, with one or two of his satellites; the nebulæ of Orion; and the nucleus or solid body of the comets. These are the principal phenomena to which the attention of the ladies would be directed in an observatory. As to the fixed stars, they appear only like very small points, even with telescopes which magnify two hundred times; their distance from the Earth being so great, that, notwithstanding these superior powers of magnifying, nothing more than small luminous, or brilliant points, can be discovered. But the utility of telescopes in this respect, consists in the thousands of stars which they bring to our view, which would otherwise be invisible to us. I have already determined 50,000 in the horizon of Paris; and double that number may be discovered with a telescope of seven or eight feet.

CHAPTER THE FIFTEENTH.

On the Plurality of Worlds.

THE near resemblance, which we have seen, in the preceding observations, between the other planets and the Earth, has led to the belief of a plurality of worlds. This interesting idea was rendered very popular by Fontenelle, in his time; but it is of a much more ancient date. The Pythagoreans and Epicureans considered that the stars were worlds, inhabited like the Earth, and that there was an infinite number of others which were invisible to us. The stars, however, must be distinguished from the planets, as those stars which have evidently a light of their own, can be compared to the Sun only; and it is impossible to conceive that any organized beings can exist in fires, which must destroy all organization.

But these stars have planets, like those of our system; and those planets may be inhabited.

"Let us suppose," says Fontenelle, "that there had never been any intercourse between Paris and St. Denis; that a citizen of Paris, who had never quitted his native town, seeing St. Denis at a distance, from the tower of Notre Dame, were asked, if he thought it inhabited, he would boldly answer, No; because I see distinctly, he would say, the inhabitants of Paris, but I perceive none at St. Denis, and I have never heard that there were any. It might be represented to him, that the distance alone prevented his seeing them from the tower of Notre Dame, and that every thing he could perceive resembled Paris exactly: that there were spires, houses, and walls; and that, consequently, it might be inhabited. But this reasoning would make little impression on our citizen, who would, no doubt, persist in asserting that St. Denis had no inhabitants, because he could see none. Our St. Denis is the Moon, and we resemble the citizen who had never quitted Paris."

There are seven planets which circulate

round the Sun; of these, the Earth is the third. All the seven move in elliptical orbits; all turn on their axes; and have the same spots, inequalities, and mountains. Four of these, one of which is the Earth, have satellites; and Jupiter is flattened at the poles, like the Earth. In short, there is not a single character visible to us in the planets, which does not bear a perfect resemblance to our globe. Is it, therefore, reasonable to suppose that the existence of living and rational beings is confined to the Earth only? What foundation can there be for such an idea, except in the weak and superstitious minds of those, whose perceptions cannot extend beyond objects of immediate sense?

Buffon felt no hesitation in calculating even the epocha at which the planets became sufficiently cool, after a long state of incaudescence, to be habitable. He conceived that the Earth required 34,000 years; that it may already have been inhabited 41,000; and that in 93,000 years more, the cold will be so intense, that the Earth will be incapable of vegetation, or organization.

This is not the case (according to Buffon) with Jupiter, who being much larger than the Earth, will preserve his heat much longer: he will only be sufficiently temperate to be habitable in 34,000 years; but he will retain his heat for 374,000 years.

Those who are accustomed to consider the Sun as the source whence all the heat we experience on the Earth is derived, will find it difficult to conceive the possibility of this system; but both Buffon and Mairon have given powerful reasons to prove, that the heat of the Earth proceeds from the very centre of our globe, and that the heat of the Sun is but a very small part of that which we experience, and which is necessary to our existence. Indeed, the Sun penetrates so small a distance into the Earth, that, in caves similar to that of the Observatory at Paris, we are neither sensible of the heat in summer, nor of the cold in winter: the thermometer remains always at ten degrees.

CHAPTER THE SIXTEENTH.

On the Flux and Reflux of the Tides.

THE causes of the tides being purely astronomical, are a natural subject of consideration in this place: indeed, the flowing and ebbing of the sea is one of the most striking phenomena of the power of attraction. Daily, when the Moon passes the meridian, or some time after, the waters of the ocean rise on our shores. This elevation has been observed at St. Maloes, to amount to no less than fifty feet: when arrived at that height, the waters gradually retire, and about six hours after their greatest elevation, they are at their lowest ebb. When the Moon passes the inferior meridian, they rise again; by which means there are two tides of flood and two of ebb, in every twenty-four hours; and each day these happen forty-eight minutes later, more or less, correspond-

ing with the Moon's passage over the meridian.

Another phenomenon of the tides, is their great increase at the time of the new and full Moon, or about a day and a half afterwards: this increase is particularly evident when the Moon is nearest to the Earth, at which time she has, of course, a greater power of attraction.

Solid terrestrial bodies are likewise attracted by the Moon, although it occasions no change of place, because a trifling diminution in gravitation is not sufficient to displace them. It is easy to conceive, that the Moon, in passing the meridian, may raise the waters of the ocean; but that they should rise both in the zenith and nadir at the same time, is more difficult to comprehend. The reason is this, that as the waters nearest to the Moon are elevated because they are most influenced by her attraction, so those on the opposite side of the Earth being but slightly attracted, are, as it were, left behind; both of which produce the same effect with respect to us. Let us suppose, for instance, a removal, or

change of place, of five feet for the centre of the Earth, seven feet for the waters on the side towards the Moon, and three feet only on the side opposite to her. It is evident that the waters would then appear raised two feet, in respect to the Earth, on both sides; that is to say, on the side towards the Moon, and opposite to her.

The Sun, likewise, occasions a part of the elevation of the tides, for which reason they are higher at the new and full Moons, because at that time the power of attraction in these two luminaries is united, and both produce the same effect. But when the Moon is in her quadrature, the Sun destroys nearly a third of her attraction. Hence, the mean tides at Brest are eighteen feet three inches at the time of the new or full Moon, and only eight feet five inches when she is in her quadrature; the Sun, therefore, produces four feet eleven inches of the tide, and the Moon thirteen feet four inches. But the Moon's attraction is increased two feet and a half, when she is in that part of her orbit nearest to the Earth, and diminishes in proportion, when she is at her

greatest distance, which sometimes occasions a considerable increase in the high tides, and a diminution in the low ones. At Brest, the tides have been known to rise as high as twenty-three feet; but this extreme elevation is produced by the wind, which forces, or displaces the whole mass of waters, and occasions a rise or depression, of about a foot and a half more than the natural state of the sea during a calm. As the westerly wind is generally very strong at the end of March and September, the equinoctial tides at Brest are considered to be the highest in Europe.

A great difference is likewise produced in the tides, by local circumstances. In the open sea they do not rise above three feet; but they are much higher, as I have already observed, at St. Maloes, because the waters are there restrained by a very narrow channel, confined likewise in a gulf, and reflected, or driven back, by the English coast.

It is from such circumstances that the flow, or high tide, does not happen exactly at the time when the Moon is at her greatest dis-

tance, or nearest to us. The friction on the coasts and on the bottom of the sea, and the tenacity and adherence of the particles of the water, are likewise so many obstacles which retard it. At the Cape of Good Hope, the tide is at its greatest height in two hours and a half; on the coast of Gascony, three hours; at St. Paul de Leon, in Brittany, four hours; at St. Maloes, six hours; at Havre de Grâce, nine hours; at Boulogne, eleven hours; at Dunkirk and at the mouth of the Thames twelve hours, where, on the day of the new Moon, high water, which ought to happen at noon, takes place at midnight, because the tide is twelve hours in passing the Channel, or the Straits of Dover, before it reaches Dunkirk. On our coast, the tide flows nearly at the rate of twenty leagues an hour.

Having once ascertained the time of high water on the day of the new and full Moon, it is easily known afterwards; it being later, by three quarters of an hour, every day, corresponding to the Moon's motion.

In small seas, the tides are not so apparent, because they are less affected by the Moon's

attraction. At Toulon, in the Mediterranean, the tide does not rise above a foot, and it is high water three hours after the Moon's passage over the meridian; but when the wind is high, it produces a much greater effect than the tides, which are, therefore, scarcely to be distinguished. For this reason, it is said, that there is no regular tide in the Mediterranean; but in the Adriatic, where the waters are obstructed, and obliged to rise, its effects may be perceived, very evidently, twice a day, as I have observed in my *Voyage d'Italie,* and in my *Treatise on the Flux and Reflux of the Tides.*

CHAPTER THE SEVENTEENTH.

On the Discovery of the Planet Herschel, or Uranus.

THE discovery of the planet Herschel, proves the advantages resulting from a profound study of the sciences, by which we frequently find treasures unsought, and even unsuspected. Dr. Herschel, whose name has justly been given by astronomers to this planet, discovered it, when at Bath, on the 13th of March, 1781, with a powerful telescope of his own construction; not being, at that time, aware even of its existence. He was making observations on some stars of the fifth and sixth magnitudes, in the constellation of the Twins, when, near the star η, he, by its motion, discovered this planet; but, conceiving it to be a comet, he wrote to Mr. Messier, at Paris, on the 9th of May, to that effect. Mr.

Messier had been before apprized of this interesting discovery, by a letter from Dr. Maskelyne, Royal Astronomer, dated the 5th of April, 1781, upon which he immediately commenced his search for the supposed comet, and having discovered it on the 16th, he communicated the result of his observations to Mr. Bourchart de Saron, who devoted much of his time to the study of astronomy, and particularly to the calculation of the orbits of comets. Mr. de Saron endeavoured to discover the elements of the supposed comet, by his usual method of calculation; but he found it impossible to make three observations agree with each other, the last never according with the two first, and his calculations always indicated a very great distance.

On the 8th of May, 1781, Mr. de Saron being satisfied that the object Dr. Herschel had discovered was, in fact, a planet, he, by calculating its distance to be twelve times that of the Sun, for the first time found his observations agree.

When the geometers and astronomers of the Academy (among others, Père Boscovick,

M. M. de la Place, Luxell, and De Lalande) were informed of this discovery of M. de Saron's, they, before they were apprized by him of its great distance from the Sun, began calculating its elements as for an ordinary comet, in a parabola; but their attempts were as fruitless as those of M. de Saron had at first been. At length, founding their calculations on the distance given them by that gentleman, their conclusions proved perfectly satisfactory; demonstrating, beyond a doubt, that the supposed comet was a planet, situated at nearly double the distance of the planet Saturn from the Sun, and that it completed its revolution in eighty-three years.

We may, therefore, without detracting from the merit due to Dr. Herschel, attribute a part of this discovery to Mr. de Saron, a gentleman justly celebrated during his life, among all lovers of the sciences in France, and whose untimely death, under the atrocious reign of Robespierre, has been universally lamented.

Dr. Herschel has likewise discovered six satellites which accompany this planet; but, from their great distance, their theory is yet imperfect.

He has, however, ascertained that they move from west to east, in orbits almost perpendicular to the plane of the ecliptic. The second and the fourth only have been observed at the same time, with sufficient exactness to determine their greatest elongations and periodical revolutions; and these are found to be subject to the general law, *that the squares of their times are in proportion to the cubes of their distances.*

On this principle, the periodical revolutions of the other satellites have been deduced from their greatest observed elongations, which will be found in the following table.

Mean distances, the diameter of the planet being 1.		Duration of their revolutions.
		Days.
First Satellite	13,120	5,8926
Second Satellite....	17,022	8.7068
Third Satellite.....	19,845	10,9611
Fourth Satellite ...	22,752	13,4559
Fifth Satellite	45,507	38,0750
Sixth Satellite.....	91,008	107,6944

CHAPTER THE EIGHTEENTH.

On the Discovery of four new Planets.

FOUR other planets have lately been discovered, to enrich our solar system; the first of which was observed at Palermo, on the 1st of January, 1801, by Mr. Piazzi, Astronomer to the King of Naples. It is situated between Mars and Jupiter, and makes its revolution in four years, seven months, and ten days. Mr. Piazzi calls it Ceres Ferdinandea.

The second was discovered on the 28th of March, at Bremen, by M. Olbers, a distinguished astronomer. Its period and distance are nearly the same as those of the first planet; and its revolution is made in four years, seven months, and twelve days: but its inclination from the ecliptic is thirty-five degrees. Mr. Olbers has named this planet Pallas.

The third was first observed by Mr. Harding, on the 4th of September, 1804, at Lilinthal, near Bremen. Its revolution is made in four years and four months, according to the calculations of M. Burchhardt and M. Gaufs, which is nearly the same as the two former. This planet is very small: its inclination with the ecliptic is thirteen degrees, and it is called Juno.

The fourth planet which we have to add to our system, was observed on the 19th of March, 1807, by Dr. Olbers, of Bremen, who discovered Pallas. This planet, which he calls Vesta, appears like a star of the fifth or sixth magnitude, and shines with a pure light, in which it differs from the other three, Ceres, Pallas, and Juno, which seem to be enveloped in a very thick atmosphere. It is, also, something nearer to the Sun than the other three, which circulate at equal distances from him, and, consequently, in equal times; whereas, the revolutions of the planets anciently known are very irregular.

Mr. Olbers is of opinion, that these four

small planets may be fragments of a considerable one, which formerly circulated at the same distance between Mars and Jupiter. Upon this supposition, he concludes that the orbits of all the fragments of the planets must cut the heavens in two opposite points; and the observed course of Ceres and Pallas, shews that these two points of reunion are in the constellation of Virgo and the Whale. In fact, it was in Virgo that Mr. Olbers discovered Pallas, and in the Whale that Mr. Harding found Juno; and Vesta, in the wing of Virgo, seems to add a new degree of probability to this conjecture, which ingenious idea has directed M. Olbers in all his enquiries. To find the other fragments, which have as yet escaped our notice, it will be advisable to make several observations in the course of every year, examining, carefully, all the small stars which compose these constellations.

An extensive field is here opened to the speculation of the natural philosopher:—a world, probably larger than ours, dashed in pieces, no doubt, from its contact with a comet! Perhaps this planet was accompanied

by satellites, and the last which Dr. Olbers discovered, which he calls Vesta, might possibly have been one of these, as it appears to have some qualities different from the rest, and circulates at a small distance within the orbits of the other fragments. Future observations may, perhaps, produce new discoveries on this subject, which is one of the most interesting in the solar system.

Names of the planets.	Times of their revolutions, sidereal.	Mean distances from the Sun, the Sun's distance being considered as one.
	Days.	
Mercury,	87,969	0,387
Venus,	224,700	0,723
The Earth,	365,256	1,000
Mars,	686,979	1,523
Jupiter,	4332,596	5,202
Saturn,	10758,969	9,538
Uranus, or Herschel,	30688,712	19,183
Ceres,	1681,539	2,767
Pallas,	1681,709	2,767
Juno,	1590,998	2,667
Vesta,	1335,205	2,373

The above table is extracted from the almanack published by the *Bureau des Longitudes* at Paris, for the year 1812. To have the mean distances of the planets in semi-diameters of the Earth, we have only to multiply the numbers in the third column of this table by 2357, which gives, also, the distance of the Sun from the Earth, in semi-terrestrial diameters.

Finis.

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ERRATA.

Preface, page xvii. line 19, *for* Philadelphia *read* Philadelphus.
Page 50, line 22, This remark alludes only to the last century.
—— 108, —— 19, *for* incaudescence *read* incandescence.
—— 117, —— 8, *for* Bourchart *read* Bochart.

Kodak Gray Scale

C Y M

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A 1 2 3 4 5 6 M 8 9 10 11 12 13 14 15 B 17 18 19

inches 1 2 3 4 5 6 7 8

cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

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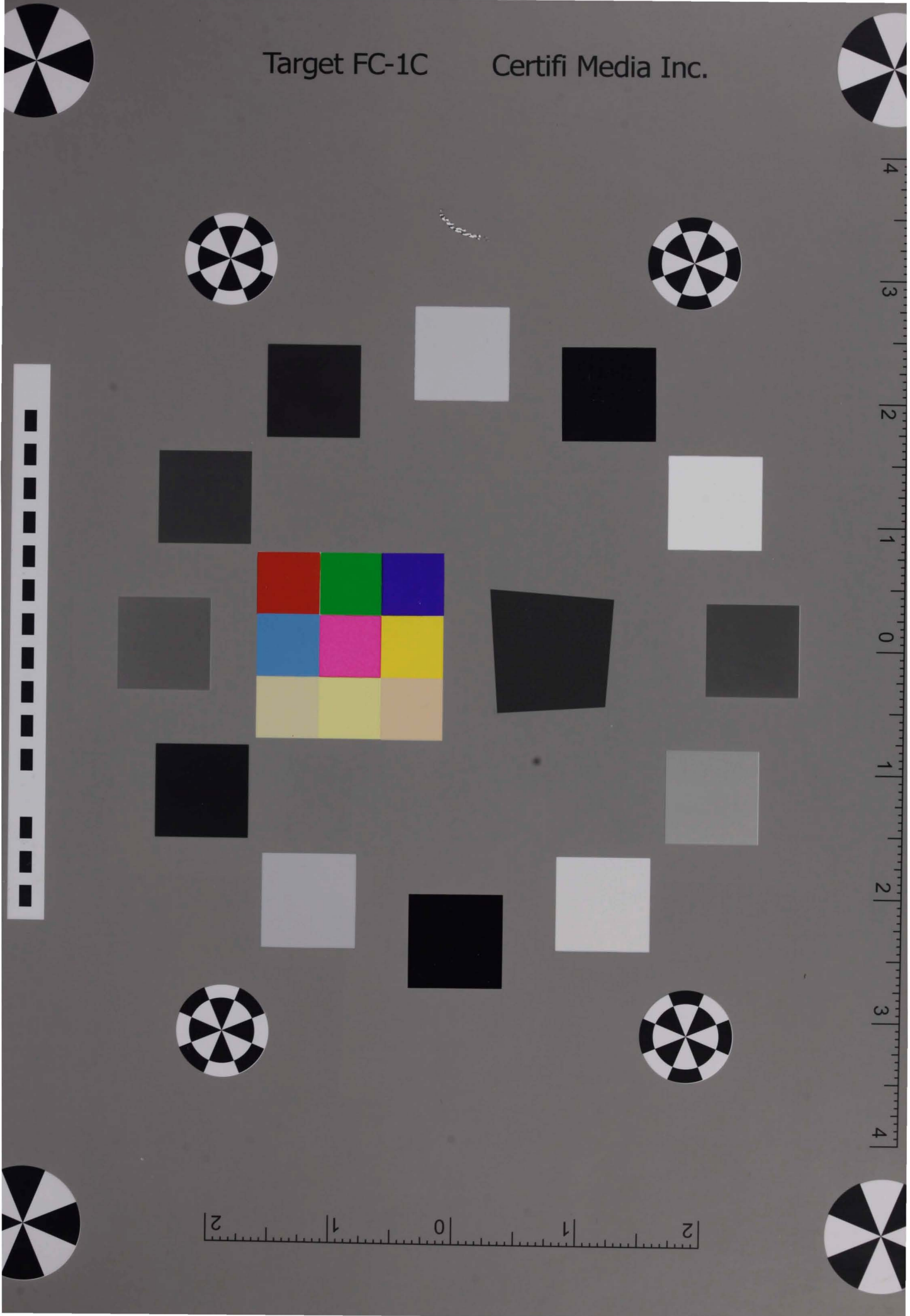
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