

## UNIVERSITY LECTURES.

## ASTRONOMY.

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## LECTURE I.

*Astronomical Science defined.—Viewed in all ages with the most profound interest.—Copernicus, Kepler, and Newton.—The Earth as an Astronomical body.—Its Figure.—How determined.—Its dimensions.—How demonstrated.—Its position in space.—Up and Down only relative terms.—Our Antipodes.—Earth's Diurnal Rotation.—Apparent Diurnal Rotation of the Starry Sphere.—Rotation of the Earth demonstrated on mechanical principles.—Also demonstrated by falling bodies.*

ASTRONOMY is that science which treats of the figures, magnitudes, distances, motions, relative positions, appearances, and physical constitutions of the great bodies which compose the visible universe; or, in other words, it is that department of science which has for its object to investigate the phenomena of worlds, which exist in countless numbers in the immensity of space. It is that science which lifts the veil of obscurity, and exhibits the grand scenery of the universe as it existed in ages past, as it now exists, and, if not interfered with by causes unknown, as it will exist in ages to come. It is that science which above all others, is calculated to give us the most profound, sublime and exalted views, of the power, wisdom and goodness of that Being who formed those magnificent systems from the eternal elements, and devised laws, calculated to maintain their stability through all their complicated and infinite variety of movements, for indefinite ages to come.

This is a science which has engaged the attention of individuals, nations, and generations from the earliest period of man; for what rational being can look upward into the blue vault of heaven, and behold the sun in its effulgent glory; the moon, shining with a silvery brightness, exhibiting its ever-varying changes; the stars bespangling the vast concave of a nocturnal sky, twinkling, as it were, with joy, and lighting up the dark unfathomable abyss of an unknown immensity; what rational being, we again enquire, can behold this august and sublime scenery without feeling the most intense desire to unlock the heavenly archives, and read, from the great book of creation, the grand science of the origin of worlds, the laws by which they are governed, and their eternal destinies? Kings upon their thrones, and the humble shepherd in the field, have alike participated in this sublime emotion. The poet enraptured with the magnificent glories of the heavens, has poured forth his sublimest effusions in the most melting harmonious strains of glowing eloquence. While the man of God, with loftier views and higher aspirations, has soared aloft from nature up to nature's Author, and, overpowered with the infinite greatness and resplendent glories which surround him on every side, he bows in humble adoration before the Great Eternal, and exclaims, "What is man that thou art mindful of him, or the son of man that thou visitest him."

This sublime science is said to have been cultivated in the earliest ages, by the antediluvian patriarchs, also by the Chaldeans and Egyptians a few centuries after the flood, and by many from the days of Moses until Christ.

Passing over many distinguished and celebrated astronomers of ancient times, we merely observe that during the dark ages, ignorance usurped its dominion over the mind of man, and the light of ancient astronomy became nearly extinguished from the world. The earth was assumed to be the stationary centre of the universe, around which the sun, moon, and stars were said to perform their revolutions. Eccentricities, cycles and epicycles were invented to account for the irregular motions among the planets, and the whole system of astronomy became encumbered with absurdities invented to uphold the false theories of Ptolemy and Aristotle, which held for many generations an almost universal sway over the mind of man.

Copernicus, at the beginning of the sixteenth century, broke through, in a measure, the superstition and ignorance of his predecessors, by transferring the centre of the planetary system from the earth to the sun, and thus forming the heliocentric theory to account for the phenomena observed.

Kepler, nearly a century afterwards, discovered the elliptical theory of the planets, and overturned the favorite hypothesis of circular orbits, which had, up to that time, been universally received. He also discovered the law of motion in elliptical orbits, and unfolded the relation existing between their periodic times and distances.

These grand improvements in the sci-

ence of astronomy laid the foundation for the great discoveries of the immortal Newton, who revealed to the astonished nations that great law of universal gravitation, or the law of force, by which the great bodies of the universe are bound together in their respective orbits. During the last century and a half, the Newtonian system has been studied with unwearied diligence, and astronomy has been rescued from the errors and absurdities of the dark ages, and established upon the firm foundation of mathematical certainty, which can never be overthrown.

It is the Newtonian system which we shall endeavor to illustrate in the present series of lectures, and to which we earnestly solicit your undivided attention. We shall commence with an examination of the earth as one of the constituents of the solar system, and as the planet with which we are more immediately connected, and as the station from which all the others are seen. If we form erroneous opinions in relation to the earth, the same errors will be interwoven, in a greater or less degree, with all our notions concerning the other bodies of the system. If we suppose the earth to be a flat, extended plane, the phenomena exhibited in the heavens, as seen from different points of its surface, would be inexplicable. If we suppose it to be stationary, the motions observed among the heavenly bodies can no longer be considered as *apparent*, arising from the motion of the earth, but as the *real* motions of the bodies themselves, many of which would appear inconceivably strange, if not absolutely absurd, being subject to no regular law of order, which characterizes other phenomena with which we are acquainted.

If the rising generation among these mountains were to grow up without any instruction in regard to the form, magnitude, and motions of the earth, only what they should gain by their own observations, their first impression would be that the earth is a kind of concave valley, bounded by mountains on every side; but after an exploration of fifty or a hundred miles, their views would be somewhat enlarged; they would now consider the surface of the earth a succession of hills and valleys, delineated upon a comparatively flat plane. All ideas concerning the extent or thickness of this plane would be exceedingly vague and uncertain. Some might suppose it to be limited by an awful precipice extending down through the infinite depths of space. Others might suppose the earth itself an infinitely extended plane without boundaries in any direction, except its upper surface.

We will now suppose that an exploring company should be selected and fitted out to explore the earth in an eastern direction. When they had travelled due east between seventeen and eighteen thousand miles alternately over land and sea, what would be their astonishment at finding themselves just entering the valley of the Great Salt Lake on the west? They would scarcely believe the evidences of their senses. The only just conclusion they could form in relation to so strange a phenomenon would be that the earth was round, at least from east to west. But a question would immediately arise among them, whether the earth was round or convex in all directions like a ball, or whether it might not be of a cylindrical form, like a saw-log, or like a steam engine boiler, used on our railroads. They might suppose it to be convex from east to west, but straight or flat from north to south. This question could be decided in the following manner: If we stand on the deck of a ship at sea, when out of sight of land, we should be able to see hundreds of miles in all directions if the surface of the ocean were a level plain; indeed, were our view not obstructed by mists, fogs, or clouds, we should be able to see hundreds of miles; large continents and islands thousands of miles in the distance would be rendered visible. Observation shows this not to be the case; but we find in every direction from our station, a clear and well defined boundary, only a few miles in the distance. As ships pass over this boundary, we gradually lose sight of them, the hull disappearing first, then the lower sails and finally the top-sails seem to sink out of sight as they recede in the distance. After they have thus disappeared, the most powerful telescopes will not render them visible; but by ascending to the mast head, they seem gradually to rise again above the horizon and are distinctly visible to the naked eye, which clearly demonstrates that it is not owing to any incapacity of the organs of vision to see further, but that the convexity of the water intervenes between the eye and the object and thus hides it from our view.

Since the same effects are observed from every part of the ocean, and in every possible direction, north and south as well as east and west, it follows, that the same convexity must prevail on every side; and therefore, that the earth cannot be of a cylindrical form, but must be round like a globe.

Another demonstrative proof that the earth is a globe, is given by considering the form of the earth's shadow when it falls upon the surface of the moon during a lunar eclipse. When the moon passes directly behind the earth so as to form a straight line with the earth and sun, the shadow of the earth, extending in a direction opposite to the sun, will fall upon the moon, and will at all times appear circular upon the moon's disc. If the earth were considered stationary, and if a lunar eclipse should always happen at the same hour of

the night, this would be considered unsatisfactory evidence of the globular figure; for there are many bodies, besides a globe, which will, in certain positions, cast a circular shadow. A grindstone, a sugar-loaf, or even a log of wood, when held with its circular end facing a light, will form a circular shadow in the opposite direction.

Now in order to determine the true figure of either of these bodies from its shadow, let different sides alternately face the light, and we shall soon be able to declare its true figure with mathematical certainty. Let different sides of the earth be presented towards the sun, and if the shadow still continues to be circular, we know the earth must be a globe, for no other figure is capable of producing a circular shadow when its different sides are exposed to the sun in a variety of positions. For instance, if a lunar eclipse were to happen at six o'clock in the evening about the first of January, and another should happen at some future period, about the same time of year, but at twelve o'clock at night; then the side of the earth presented to the sun during the former of these eclipses would be at right angles to the side presented during the latter; yet in both instances its shadow upon the moon would be circular. This, then, is a conclusive demonstration of the globular figure of the earth independent of its diurnal and annual revolution. But if the diurnal rotation of the earth be admitted, then we shall have almost every side of the earth successively turned towards the sun; and eclipses happening within a comparatively short period of time, under all these conditions.

By such observations as these, the earth is proved to be of a globular form by the most incontrovertible evidence.

When we come to speak of the diurnal rotation of the earth upon its axis, we shall again refer to its figure, and show that there is a slight deviation from the globular form, arising from causes connected with that motion. But for all practical purposes, wherein great nicety or precision is not required, the errors which arise by assuming the earth to be a perfect sphere, will be inappreciable.

Objections have been raised to the globular form of the earth on the ground that the great inequalities existing on its surface under the name of mountains and valleys are inconsistent with such a form; but the highest mountains of our globe when compared with the earth itself, would be only about one-sixteenth hundredth part of its diameter. The roughness on the surface of an orange is far greater, when compared with the magnitude of the orange than is the roughness of the surface of the globe when compared with its magnitude. Indeed, if our globe were reduced to the size of an orange, the mountains delineated upon its surface, if reduced in the same proportion, would require a microscope of considerable power to clearly discover them.

Having determined that the earth is a globe, we shall next inquire, how its magnitude may be determined. If any means can be devised by which we can measure the circumference of the earth, its diameter, together with the number of square miles upon its surface, and also its solid contents, can be easily calculated. Now to measure the whole circumference of the earth with a chain, or line, or any other accurate measure, would be altogether impracticable on account of mountains, oceans, swamps, and other opposing obstacles. But if we can accurately measure a portion of this circumference, for instance, one degree of latitude, and find how many miles it contains, all that would be necessary would be to multiply the number of miles in one degree by 360, which is the number of degrees in the whole circumference of the earth, and the product would be the number of miles around the earth. Now a degree may be measured as follows: let the latitude of this tabernacle be accurately taken by some astronomical instrument of great perfection, then measure due south, until you reach the southern extremity of the valley, being careful to select a measuring rod whose length has been determined with the greatest possible accuracy. When this measuring rod is used, it must, each time, be carefully adjusted to a perfect level, and its temperature noted; for the length of any metallic bar varies with its temperature. When the measurement is finished, at the southern extremity, erect your astronomical instrument, and by a series of observations of the heavenly bodies, determine the latitude of this second station, which we will say is one-half of a degree south of the first station, and the distance measured we will also say is 34½ miles, this doubled would be 69½ miles, or the length of one degree; this multiplied by 360 would give 25,020 miles for the circumference of the earth; this divided by 3.14159 would give 7964 miles for its diameter. As the average length of a degree is not quite 69½ miles, these numbers are rather too large.

To those unaccustomed to traveling, it is difficult to convey a correct idea of the magnitude of the earth in numbers. But as we are now addressing a people who have traveled over no inconsiderable portion of the earth's circumference, they will be better prepared to form more correct notions on this subject, by comparing the distances over which they have traveled with the numbers expressing the distances around and through the earth. The distance from Ogden to Omaha by the railway, is, in round numbers, about 1,000 miles.

The diameter of the earth is nearly eight times that distance; while the circumference is nearly twenty-five times that measure. If we could pass around the earth with our ox teams at the rate of 10 miles per day, it would require about seven years to perform the journey. If we were to travel on a railroad car at the average rate of 20 miles per hour, day and night, it would require about 52 days to accomplish the great undertaking. But however great this distance may appear, it dwindles into comparative insignificance, when contrasted with the sun, and many of the other stupendous bodies of our system.

Having determined that the earth is a globe of definite magnitude, the next question which would naturally occur to the uninformed is, upon what does it rest? Has it any solid foundations? These questions naturally arise, from the constant habit which we have of associating foundations with all the objects perceived upon the surface of the earth. Without some kind of support, all terrestrial objects have a constant tendency to fall perpendicularly to this surface. We have never seen any exceptions to this general law, and therefore, when we think of the earth as a whole, we naturally suppose that it must fall, unless supported by something; but a few moments of reflection will convince us that the force, whatever it may be, which causes all objects to fall or press towards the centre of the earth, will have no tendency to cause the earth as a whole to move in any direction. Forces which press equally and in opposite directions will be in equilibrium, and cannot produce motion.

If the forces of any two opposite hemispheres of the earth, taken in any position, be equal, as they are in opposite directions, they cannot produce motion; therefore the earth, under such forces, existing within itself, will have no tendency to go in one direction more than in another. Hence, unless it were influenced by bodies external to itself, it would remain at perfect rest in any part of space where it might be placed.

The earth, under these conditions would have no *up* nor *down*, relative to the different points of space with which it is surrounded. Up and down are relative terms, and when applied to the earth, signify *from* and *to* its centre. It will easily be perceived that the earth could not fall down towards its own centre, so as to alter the position of that centre in space; neither could it as a whole move from that centre in any possible direction. Because we see a wooden globe have an *upper* and an *under* side relatively to the earth in any given position in which it may be placed, we are apt to transfer the same property to the earth, and suppose it to have an upper and under side in relation to the space enclosing it; but this is an illusion, formed by habit, which we must entirely divest ourselves of, in order to form correct ideas of the earth existing in space without foundations on which to rest. If any one of this audience were placed alone in space where there was no attractive matter, and no other bodies existed, he could not conceive of either up or down. As he would have no tendency to move in any direction, the terms over, under, above, below, etc., would have no meaning whatever to him. If he were to take a bushel of apples and throw them in every possible direction, he never could lose one of them; for by the power of gravity, each one would return to him, having the same velocity as when projected from him. If he were to fire a bullet directly from him, though it would be absent for many hundreds of years, and pass over many thousands of miles in space, yet, by the force of gravity, it would return again and penetrate his body, having the same velocity as when projected from the mouth of the gun. The direction of the apples, or of the bullet would be up or down as they proceeded from or towards the body that gave them the projection.

Our antipodes, or the inhabitants of Desolation and Amsterdam islands, situated in the Indian Ocean, are on the opposite side of us; their feet point towards ours; their zenith, or that portion of the sky which is over their heads, is directly under our feet; and yet they have no more tendency to fall towards their sky than we have towards ours; all bodies around them have the same tendency to press towards the surface of the globe there, that they have here: the Indian Ocean is no more likely to be poured out into their sky, than the Salt Lake is into ours. Magnets, placed on opposite sides of an iron globe will adhere to its surface, and will revolve with it without falling. A powerful magnet, held two or three inches from the under surface of an iron globe, will fall upward to that surface, the same as a stone will fall downwards upon the surface of the globe of the earth. All directions towards the centre of an iron globe, are down to the magnet; all directions from its centre are up. All who wish to make any progress in astronomy, must familiarise their minds with the right conception of up and down, ascending and descending, above, below, and such like terms, always remembering that they are terms which relate only to the centre of forces, and that they change their direction as often as we change the position of objects in relation to that centre.

We have now demonstrated that the earth is of a globular form, and of a determinate magnitude; that it exists without any external supports or foundations, surrounded on all sides by space; and that bodies can exist on all sides of its surface without any