UNIVERSITY LECTURES.

ASTRONOMY.

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LECTURE IV.

The Seasons.—Subdivisions of the Ecliptic into Signs.—Precession of the Equinoxes.—Sidereal and Tropical year.—Revolution of the elliptic orbit.—Anomalistic year.—Geocentric and Heliocentric places of a Heavenly Body.—Earth's Mean and True Longitude.—Mean and Apparent time.—Distributions of Temperature.—Hottest and Coldest days of the year.—Permanency of the mean annual temperature.—Invariability of the earth's diurnal and annual Periods.—Stability of the Laws of Motion.—Interior Temperature of the earth as affected by the Sun.—Ocean Temperature.—Cause of the great Currents in the Ocean.—Atmospheric Phenomena.—Reflections on the Origin of Planetary Motion.

THE first subject which we propose to investigate in this lecture is the Seasons. During the time that the earth performs one annual revolution, the inhabitants experience a variety of seasons.

Those who live in the southern hemisphere have their seasons in the reverse order of those in the northern. December, January and February are their summer months; while here, they are our winter months. Their spring corresponds to our autumn; their winter to our summer; their autumn to our spring. When the days in the northern hemisphere are the longest, in the southern they are the shortest; and *vice versa*; when they are the shortest here, they are the longest there. From the 21st of March to the 21st of September, the sun shines without any intermission on our north pole, while the south pole during that time is enveloped in darkness. From the 21st of September to the 21st of March, the south pole is constantly enlightened by the sun, while our north pole is left in darkness. The whole order of the seasons in the northern hemisphere is repeated in the southern, but during the opposite time of year.

If the earth revolved around the sun directly from west to east, that is, if the plane of the earth's orbit coincided with the plane of the equator, there would be no variety of seasons; and also the days and nights over the whole earth would be of equal length. If the earth revolved around the sun from south to north, and back again to the south, then our seasons would have the greatest possible change that could be given to them. The difference between the length of days and nights would increase with much greater rapidity, and the extremes of temperature between summer and winter would also be far greater. On the 21st of March the days and nights would be equal in all latitudes; from that time until about the 10th of May, the days would in our latitude increase from 12 hours to 24, while the nights would decrease from 12h. to nothing. From the 10th of May to the 2nd of August, the sun would not set to us; but he would be seen among our circumpolar stars, exhibiting the same apparent phenomena manifested by those stars. About the 2nd of August night would again set in, the length of which would now increase until the 21st of September, when the days and nights would again be equal. From the 21st of September the length of the nights would increase until about the 11th of November, when the sun would set and remain below the southern horizon about eighty days, or until about the 31st of January, when the day would set in being only a few minutes long at first, but increasing rapidly in length until the 21st of March, when day and night would again be equal.

Thus if the earth revolved in an orbit whose plane was perpendicular to the plane of the equator, the vicissitudes of the seasons and the variations of day and night would be such as to render our globe unfit for the habitation of man. At one season of the year he would be scorched not only with a vertical sun, but with an accumulation of heat arising from the great length of the day; while at another season he would be exposed to all the severity of cold experienced in the polar regions.

If the earth should revolve around the sun in any other direction, except the two that we have already mentioned, the difference of the seasons, and of day and night would be proportional to the inclination of the ecliptic to the plane of the equator, as the angle of inclination increases so would the differences in the severity of the seasons increase. This inclination of the two planes is called the Obliquity of the Ecliptic, which is about 23deg. 27min. 30sec. of an arc.

We shall next point out some interesting phenomena connected with the earth's annual motion, or explain what is meant by the signs of the zodiac—the precession of the equinoxes—the tropical, sidereal and anomalistic years—the mean and true places of the earth in its orbit—and mean and apparent time; after which we shall again recur to the phenomena of the seasons and their effect upon the earth's temperature, or climatic changes.

From the 21st of December to the 21st of June the earth pursues a direction, not due east, but nearly east south-east; from the 21st of June to the 21st of December its direction is nearly east north-east. In December the earth, as seen from the sun, is in Cancer; while the sun appears in Capricorn.

It is evident, that while the earth goes east south-east from Cancer to Capricorn it must pass from the north through the equinoctial plane to the south; the earth crosses the equinoctial about the 21st of March; it is then in the first point of Libra, while the sun appears in the first point of Aries. When the earth goes east north-east from Capricorn to Cancer, it recrosses the equinoctial from south to north about the 21st of September, when it is, as seen from the sun, in the first point of Aries, and the sun, as seen from the earth, appears in the first point of Libra.

As the earth goes round its annual circuit it maintains its axis parallel to itself, that is, the angle of its inclination to the plane of its orbit remans the same through out an entire revolution; consequently the axis will be directed towards one particular point in the infinite sphere of the heavens; in other words, if the parallel lines, represented by the parallel position of the axis in every point of its orbit, were produced to the immense distance of the starry sphere, they would seem to coalesce in one point. Therefore the stars, because of their great distance, would not exhibit any appreciable parallax or displacement by the earth's annual motion; that is, the whole orbit of the earth, if seen from the distance of the fixed stars, would appear like a mere point, subtending no apparent angle. Now if a line be drawn from the sun to the earth, it will be perpendicular to the axis of rotation, when the earth is in the vernal and autumnal equinoxes, hence the days and nights will be equal.

At all other seasons of the year, the angle which the radius vector makes with the axis of rotation, deviates from the perpendicular; this deviation on either side of the perpendicular is equal to the sun's north or south declination: when the sun is in either of the tropics, the deviation is at its maximum, and is then equal to the obliquity of the ecliptic.

All the variety of seasons, together with the differences of the length of day and night, are the results of the continual variation of this angle, and the variation of the angle which the radius vector makes with the earth's axis, is the result of the obliquity of the ecliptic, combined with the parallelism of the axis in different points of the orbit.

The ecliptic is divided into twelve parts, called Signs; each sign, therefore, contains 30 degrees.—These signs are reckoned from the vernal equinox, and are called Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces. These signs are merely names given to the subdivisions of the ecliptic, commencing from the actual equinox which is constantly shifting its position in respect to the fixed stars, retreating upon the ecliptic westward at the rate of about 50.1 sec. of an arc per annum. The signs of the ecliptic, therefore, must not be confounded with the constellations, or certain clusters of stars which are called by the same names. A little over two thousand years ago, the signs of the ecliptic were coincident with the constellations that bear the same names; but during that period the actual equinox has receded upon the ecliptic about one full sign; consequently, the constellations of the zodiac are about one sign in advance of the signs of the same name, marked on the ecliptic.

It was formerly the practice to reckon the longitude of the heavenly bodies by signs, degrees, minutes, and seconds, but the practice of using signs in the reckoning of longitudes, is now being abandoned, in consequence of the misunderstanding liable to arise from confounding these signs with the constellations; longitudes are now reckoned by degrees, &c., from 0, or the vernal equinox, to 360 degrees.

As the equinoxes recede upon the ecliptic, it is evident that the earth will not perform one complete revolution, as indicated by the stars, when it arrives at the same equinox again; the amount which it lacks of one complete revolution is, as before stated, about 50.1 sec. of a degree; over this distance, therefore, the earth must move in order to complete one sidereal year. The time of describing this arc is 20m. 19.9s. Hence the sidereal year is so much longer than the tropical year: the former is equal to 365d 6h 9m 9.6s; while the latter is equal to 365d 5h 48m 49.7s. It is during the tropical, and not the sidereal year, that our seasons come round in the same order.

The longer axis of the elliptic orbit of the earth has a slow motion of 11.8s per annum in advance; that is, the perihelion advances eastward upon the ecliptic, that much in a sidereal year: this small arc, which is so much over a complete revolution, must be described before the earth can again reach the perihelion point of its orbit. The time occupied in so doing, is 4m 39.7s; this added to the sidereal year, gives the interval between two consecutive returns to the perihelion. This interval is equal to 365d 6h 13m 49.3s, and is called the Anomalistic Year. The receding of the equinoxes and advance of the perihelion upon the ecliptic, are results flowing from the action of the forces existing in the solar system, and which we probably shall more fully explain should we hereafter lecture upon the law of those forces.

We shall next explain what is meant by the Geocentric and Heliocentric places of a heavenly body.

The Geocentric place is its position as it would be seen from the centre of the earth. The centre of the earth is chosen, as a convenient point of reference, because it is not affected by the diurnal rotation.

The Heliocentric place of a body is its position as seen from the sun, or rather from the centre of gravity of the solar system, which is situated near the centre of the sun. This point is chosen as a convenient point of reference, because it is not affected by the rotatory nor the orbitual motions of the system.

The Geocentric position refers the situation of bodies to the great sphere of the heavens concentric with the centre of the earth.

The Heliocentric position refers them to the sphere of the heavens concentric to an eye situated in the centre of gravity of the system.

The heliocentric longitude of the earth is its angular distance, subtended at the sun, from the first point of Aries, reckoned eastward on the great circle of the heavens, formed by the infinite prolongation of the plane of the ecliptic.

The heliocentric latitude of a heavenly body is its angular distance, subtended at the sun, reckoned either north or south of the ecliptic on circles perpendicular to that plane. As the earth is situated in the plane of the ecliptic, its heliocentric latitude is generally nothing.

We shall now explain what is meant by the mean and true places of the earth in its orbit.

The mean place is the position it would occupy if it revolved with a uniform motion in a circular orbit with the sun in its centre. Then its true longitude could be calculated by the following simple proportion:—

One year: the time elapsed : : 360 deg. : the arc of longitude passed over from the vernal equinox.

But as the orbit is not circular, and is not described with a uniform motion, this rule will not give the true longitude; the longitude thus obtained is called the mean longitude. As the earth's orbit does not deviate to any great extent from a circle, the true longitude does not differ to any great degree from the mean.

The former may be calculated from the latter by applying to it a correction which will be additive or subtractive, according as the earth is in advance or behind its mean place. The amount of this correction is computed upon the principle of the equable description of areas about the sun in equal times. The area swept over by the radius vector in any given time, may be ascertained by the following proportion:—

One year : the time elapsed : : the whole area of the ellipse : the area of the sector swept over in that time.

And having thus obtained the area of the sector, there are various methods of obtaining the angle about the sun which this fractional area would subtend in any given position of the ellipse. By the principles of geometry, the true longitude of the earth could be calculated for any given moment.

To save the labor of calculating, tables have been formed, expressing the difference between the true and mean longitude for any given time throughout the year. This difference is called the equation of the centre. At the perihelion and aphelion points of the orbit the mean and true places will coincide. From the perihelion to the aphelion the true place will be in advance of the mean; and from the aphelion to the perihelion, the true place will be behind the mean. The greatest difference between the true and mean places, amounts to 1 deg. 55 m. 33.3 sec. ; from this the difference diminishes to nothing, and is additive to the mean place, while the earth passes from the perihelion to the aphelion, and subtractive from the mean, while the earth passes from the aphelion to the perihelion.

It is a well known fact, that the sun comes to the meridian at different seasons of the year not exactly, as indicated by a well regulated clock, but some times before, and at other times after mean noon.

If the earth revolved with a uniform motion in a circular orbit with the sun in its centre, and also in a place coincident with the equator, the sun would always come to the meridian precisely at 12 o'clock. But as the earth's orbit is elliptical with the sun in one focus, and is described with velocities not uniform, the sun will not, on account of these causes, coincide with a true clock.

But independent of these, there is another cause which produces an inequality in the time of the sun's coming to the meridian; and that is the obliquity of the ecliptic: even if the earth did describe in the ecliptic equal angles in equal times, these equal angles in the ecliptic, if projected on the equator at right angles to it, would give unequal angles, and therefore this would be another cause which would make the sun come to the meridian sooner or later than clock time. Time reckoned from the position of the sun is called *apparent* time; and when reckoned from a true clock it is called *mean* time. The difference between mean and apparent time is called the equation of time.

The causes just referred to, operate conjointly to increase this difference. The greatest fluctuation of apparent time, amounts to upwards of half an hour, being sometimes 16¼ minutes faster than mean time, and at other times 14½ minutes slower. Tables of the equation of time are calculated and inserted in some almanacs; and by the application of the equation to apparent time, we can regulate our clocks and watches to mean time.

From December 24th, the sun begins to fall behind a true clock, the difference increasing daily, until it attains a maximum on the 11th of February; it then gradually decreases until the 15th of April; therefore, from the 24th of December until the 15th of April the equation is to be added to apparent time in order to obtain the mean time. From April 15th, the sun begins to be in advance of clock time, the difference increasing very slowly until it attains its maximum on May 14th, when it gradually diminishes until June 14th. From April 15th to June 14th, the equation must be subtracted from apparent time to obtain clock time. In like manner, from June 14th to August 31st, the equation must be added. And from August 31st until December 24th, it must be subtracted.

Hence there are four days in a year when the sun and a true clock, or apparent and mean time agree; namely, April 15th, June 14th, August 31st, and December 24th. Between each of these periods, there is a day on which the equation attains to its greatest additive or subtractive value. On the 11th of February the maximum amounts to 14m 32s additive. May 14th, it amounts to 3m 54s subtractive. On July 26th, 6m 12s additive; and on November 2nd, 16m 18s subtractive.

We have purposely deviated, for a while, from the subject of the seasons, to explain the nature of the tropical year on which the seasons depend, and at the same time to briefly notice some slight variations in the position of the earth's orbit. We shall now return to the inequality of day and night in different latitudes, and to the unequal distribution of temperature over the earth's surface.

If the earth revolved in an orbit coincident with the equator, as we have already explained, day and night in all latitudes would be equal the year round, each being of twelve hours duration. Under these conditions, there would be no variety of seasons. Summer and winter, spring and autumn, would not, as now alternately follow each other. The sun would be constantly vertical only in the plane of the equator. This meridian altitude in any given parallel of latitude would never vary. There would be no tropical nor polar circles, dividing the earth into torrid, temperate, and friged zones. The temperature of the earth's surface from the equator to the poles would gradually decrease; while all fluctuations of temperature, such as now result from the seasons, would entirely cease.

If the earth revolved, as we have also explained, in an orbit whose plane was at right angles to the plane of the equator, the arctic and antarctic circles would be coincident with the equator; while the northern and southern tropics would reach to the poles. The two temperate zones would cease to exist; while the torrid and friged zones would become alternately identical. Under these circumstances, the greatest extremes of temperature, and the greatest variations of day and night, would exist, that could possibly take place by any change of the angle of inclination between the ecliptic and equatorial planes. The present vegetable and animal economy could not endure the terrible extremes of temperature inflicted by such an order of things.

Were the obliquity of the ecliptic a little more than double its present value, say 49° 15′. In our parallel of latitude we should have, in December, some two weeks of night, during which only the upper limb of the sun, skimming our southern horizon a few minutes before and after 12 o'clock at noon, would be visible, if not obstructed by the inequalities of the landscape. From December to the 21st of June the nights would decrease, and the days increase. At the latter period, the sun at noon would be 8° 30′ north of our zenith; and 12 hours after, his lower limb would for, a few minutes, disappear behind our northern horizon; while his upper limb would continue visible, that is, providing the horizon is not obstructed by mountains. Under such extremes of heat and cold, the greater part of our globe would be rendered uninhabitable.

But the present value of the obliquity of the two planes is such as to produce an agreeable variety of climate whose fluctuations are moderately adjusted to innumerable organizations of both plants and animals. The varied seasons bring with them their peculiar enjoyments, and seem to stimulate the higher orders of animated beings with energy, activity, and life, to provide for the periodical changes so happily imposed upon them. While the monotony of an equable temperature and unchanging climate would enervate or render dormant many of the instincts, energies, and powers, which now so usefully and beautifully adorn the vegetable and animal kingdom.

If we suppose the heat of the sun to be constantly the same, the quantity of heat received by the whole earth each day will be constant; but the distributions of this heat