The Lancaster Intelligencer.

Volume XVII—No. 130 LANCASTER, PA., TUESDAY, FEBRUARY 1, 1881 Price Two Cents.

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TUESDAY EVENING, FEB. 1, 1881.

CELESTIAL DISTANCES.

LECTURE BY CITY SUPERINTENDENT R. K. BUEHRLE.

Fourth Regular Meeting of Star Club.

Sirius the Dog Star—Procyon—Castor and Pollux—Capella—"Starlight," Etc.

The fourth regular meeting of the Star club of the Young Men's Christian association was held last evening. Some twenty additional stars were given and their positions indicated in the prominent constellations of the Great Dog, the Little Dog, the Twins and the Charioteer, all these star groups being now in the eastern sky in the early evening.

The special topic for the evening was the Mathematics of Astronomy, or rather the use made of the triangle in determining Celestial Distances. This was discussed very clearly by Mr. R. K. Buehrle, city superintendent of public schools. In illustration of the successive steps in the development of his subject, he used large and carefully-prepared diagrams, which are of necessity omitted from our report as well as references in explanation of the same. Mr. Buehrle is a gentleman well up in scientific studies, as well as an able executive in the administration of our school affairs.

Remarks of Mr. McCaskey.

Canis Major, the Great Dog, has long been widely known. It is one of the very old constellations. In it we find Sirius, the largest and brightest of all the stars to be seen during the round of the year. It is familiarly known as the "Dog Star." As there are some people who know the North Star by name, but would be unable to point it out in the northern sky, so there are those who have heard of the Dog Star by name—and no more than this! Though it has blazed above their heads all winter long, each year of their lives, they have never recognized it in the heavens. They are familiar also with the phrase "the dog days," without any knowledge of its meaning. A few words will make this clear, and an intelligent glance into the sky will make them acquainted with the star itself. The ancients were very observant of the stars, and knowing that Sirius was shining at the same time with the Sun during a part of the summer, they attributed the increased heat of mid-summer to its influence. These days were therefore styled by the Romans *dies caniculares*, or "the dog days," Sirius being also known to them by the name of Canicula, or Dog Star. The Romans yearly sacrificed a dog to this star on behalf of their flocks and herds, as well as their lands, that these might not suffer from the drought of the hot season, when this blazing orb, which was no brighter then than now, shone in conjunction with the Sun.

Sirius may now be recognized at once at 7 o'clock in the southeastern sky, in a clear night, sparkling with extraordinary brilliancy, about twenty-three degrees southeast from the Belt of Orion. It is some twenty five degrees from Beteignese the bright star in the right shoulder of Orion, and about the same distance from Procyon, a bright star towards the eastern horizon in the Little Dog. These three stars are all of the first magnitude and form a beautiful equilateral triangle which is readily traced. It also forms a triangle nearly similar to the south with Phact in the constellation of the Dove to the southwest and Naos in the Ship, to the southeast, thus completing the "Egyptian X." Sirius being at the crossing of the lines and Betelguese and Procyon to the north. This figure can now be seen best about 10 o'clock in the evening. The motion of Sirius is estimated at 340 miles per minute and the spectroscope shows that it is moving away from our system.

The Moon is over 2,000 miles in diameter, the Earth about 8,000 miles, Jupiter over 80,000 miles, the Sun about 880,000—figures that are appalling to the imagination, but whose approximate accuracy even the elementary work of the astronomer amply attests. Accepting as correct this enormous estimate of the Sun's diameter, nearly a million of miles, what shall we say of Sirius whose diameter is rated at more than fifteen times that of the Sun! and whose awful mass is sunk into space so far that it requires nearly twenty-five years for its light—moving at the rate of 11,000,000 miles per minute—to reach our dark little earth! And yet this same light comes to us in such quantity as to make Sirius seem the largest star in all the sky.

In speaking of stars, it should perhaps be said that we never include among them the planets, Jupiter, Saturn, Venus or Mars, all of which seem of greater size than the stars, because they are, comparatively, so very near our earth, just as a globe a foot in diameter near at hand may seem larger than the Sun.

Five other stars in this constellation are named: Mirzam in the forepaw, five and a half degrees from Sirius, a star which is said to have disappeared in 1670 and was not seen again for twenty years, but which has been distinctly visible ever since that time; and the three stars forming a conspicuous triangle some twelve degrees southeast from Sirius, of which that at the vertex is Wesen, to the west in the base of the triangle is Adhara, and to the east Aludra; these two stars being about six degrees apart.

Canis Minor, the Little Dog, of which the star Procyon, has already been mentioned, is east of Orion. The word Procyon means "before the dog," rising a little before Sirius. The triangle which it forms with Sirius and Betelguese has already been given. Some five degrees west of Procyon is the faint star Gomelza in the neck of the Little Dog. These two stars make a long and narrow parallelogram with Castor and Pollux some twenty-five degrees to the north. Gomelza also forms a right-angled triangle with Pollux and Beteignese, Gomelza at the right angle.

Looking due east in the early evening at this time of year, we see somewhat to the north two stars of like brilliancy, five or six degrees apart, which make, as has already been said, a long and narrow parallelogram with Procyon and Gomelza of the Little Dog. There are the well-known stars Castor and Pollux in the constellation of the Twins. They mark the heads of the Twins, Pollux being about five degrees east of Castor. If we draw a line from Pollux to Betelguese, we find upon it two stars readily distinguished. That nearest Pollux is Wasat; the other, which marks the foot of Pollux is Alhena, twenty degrees from Pollux and about fourteen degrees from Betelguese. Tejat, a short distance west from Alhena, completes the rude parallelogram with Castor, Pollux and Alhena, and the star on the line from Tejat to Castor, nearest Tejat, is Mebusta.

These are the six stars named and easily recognized in the constellation Gemini, the Twins. With the single exception of Tejat they are all multiple stars. Castor is double, with the smaller sun revolving around the larger once in 442 years. Wasat and Mebusta are also double stars; Alhena is a triple star, and Pollux, most interesting of all, is quadruple! In ancient mythology, Castor and Pollux were invoked as the patron divinities of sea-faring men.

One more constellation and our list for this evening will be ended. It is Auriga, the Charioteer or Coachman, which contains one of the most beautiful and interesting stars in the nothern heavens, Capella, which is now nearly overhead at 8 o'clock in the evening. This bright star is found about half-way between Betelguese in Orion and the North Star. A short distance from it is a slender isosceles triangle of faint stars which are known as the Kids, the name Capella meaning "she-goat." In the chart of figures, the Coachman is represented as carrying this animal against his left shoulder. The five prominent stars in this constellation form an irregular pentagon, shaped somewhat like a boy's kite. Diagonally across this pentagon from Capella is Auriga or El Nath, which is also the tip of the western horn of the Bull. It is nearly half-way between Castor and the Pleiades. The most northern star in the pentagon is not named, while that in the right shoulder, eight degrees from Capella, is Menkalina. These two stars make a long and narrow parallelogram, its length five times its breadth, with the two stars, Betelguese and Bellatrix, in the shoulders of Orion. The distance of the bright star Capella is estimated at seventy light years, that is to say, the light which we see from it to-night left its distant source two generations ago, long before any of us were born—before the era of steamboats or railroads or telegraphs—and all that these have meant to the world in the quickening of its intellectual activity and the development of its material resources—while an infinitesimal part of the light which leaves Capella to-night will probably reach our earth in the year 1950, long after "life's fitful fever" shall have ended for most of us, and for many of us its beams will fall coldly upon our forgotten graves.

Our numerical list is therefore continued as follows: No. 47 Sirius; 48 Mirzam; 49 Muliphen; 50 Wesen; 51 Adhara; 52 Aludra—these six in Canis Major, the Great Dog; 53 Phact in the Dove; 54 Naos in the ship, both in the Egyptian X, 55 Procyon, and 56 Gomelza both in Canis Minor, the Little Dog; 57 Castor; 58 Pollux; 59 Tejat; 60 Alhena; 61 Wasat; 62 Mebusta, these six in Gemini, the Twins; 63 Capella; 64 Auriga or El Nath; and 65 Menkalina in the Charioteer.

Before leaving the Star list for the evening let me read Celia Thaxter's beautiful poem entitled Starlight, in which Capella is the bright particular star, and its light-year period so effectually used as to be impressed upon the memory. The poem may be new to many of you.

Starlight.

The chill, sad evening wind of winter blows
Across the heathland, bleak and bare and high;
Rustling the thin, dry grass that sparsely grows,
And, shivering, whispers like a human sigh.

The sky is thick with stars that sparkle keen,
And great Capella in the clear north-east
Rolls slowly up the cloudless heaven serene,
And the stern uproar of the sea has ceased.

A fleeting moment and the earth seems dead—
So still, so sad, so lonely and so cold!
Snow-dust beneath me, and above my head
Star-dust in blackness, like thick sprinkled gold.

The stars of fire, the tiny stars of ice,
The awful whirling worlds in space that wheel,
The dainty crystal's delicate device
One Hand has fashioned both—and I, who kneel

Here on this winter night, twixt stars and snow
As transient as a snowflake and as weak,
Yearning like all my fellowmen to know
His hidden purpose that no voice may speak,

In silent awe I watch His worlds: I see
Mighty Capella's signal, and I know
The steady beam of light that reaches me
Left the great orb full seventy years ago.

A human life time! Reason strives in vain
To grasp at time and space, and evermore
Thought, weary grown and baffled, must again,
Retrace its slow steps to the humble door

Of wistful patience, there to watch and wait
Devoutly, till at last Death's certain hand,
Imperious, opens wide the mystic gate
Between us and the future He has planned.

Yea, Death alone. But shall Death conquer all?
Love sighs and pleads in anguish of despair.
Sooner shall great Capella wavering fall
Than any voice respond to his wild prayer

And yet, what fire divine makes hope to glow
Through the pale ashes of our earthly fate?
Immortal hope, above all joy, below
All depths of pain wherein we strive and wait.

Dull is our sense; hearing we do not hear,
And seeing see not; yet we vaguely feel
Somewhere is comfort in the darkness drear
And, hushing doubts and fears, we learn to kneel.

Starlight and silence! Dumb are sky and sea;
Rent us death the awful spaces lie;
Speechless the bitter wind blows ever nae,
Sad as the breathing of a human sigh.

Mr. R. K. Buehrle was then introduced who spoke much as follows:

Celestial Distances.

Only the civilized and enlightened nations of antiquity have handed down to modern times, a knowledge of the science of astronomy. Primitive, rude, uncultured tribes, possess no science. They see the stars, indeed, but they do not know them. Neither their physical nor their mental activities are worthy of the pen of the historian, and although their acquisitions may be useful to succeeding ages, they are, like the foundations of the pyramids, beneath the surface and hence invisible to the ordinary observer. It is not only interesting but also highly instructive to trace the progress of any science from the earliest feeble, uncertain, halting, at times retrograding, steps of the infant, to the later, firm, steady, at times rapid and triumphant strides of the giant; for if we attentively observe the progress of human culture, we can easily see how the mind grows more acute with the growth of the field offered to its investigation.

To those who have been wafted on the wings of the imagination to the remotest nebulæ, and who have revelled in the glories of the heavens, it may seem rather prosaic to return to mother Earth, but when it is remembered that the science of the heavens depends on that of the Earth, that *astr*onomy is founded on *ge*ometry, and that after we have seen the operation of the wonderful celestial mechanism, we naturally inquire *how* all this is known, and are anxious to understand and not merely to wonder at and admire—the propriety of this evening's work will probably not be questioned.

Who first arrived at a knowledge of the form of the Earth, will most likely never be known, notwithstanding that the discovery that the Earth is not a plane has been ascribed to Thales of Miletus (born about 640 B. C.) who believed it to be a spherical figure. The beginnings of every science are shrouded in obscurity so deep as to defy the pen of the historian, and it is only after great progress has been attained, that the results, with the names of those who have contributed to their attainment, are inscribed on the scroll of fame. The votaries of every science may be classified as those that are forgotten, those that are martyred, and those that are glorified.

If we believe Dr. Seiss, Abraham, or Job, or Melchisedek, was possessed of a greater knowledge in astronomy, than modern scientists; but as the only record of their astronomy is said to be wrought into and embodied in the Great Pyramid, and as the characters are variously interpreted, we will rather confine ourselves to those records concerning which there is very little, if any, difference of opinion. Not knowing who discovered the fact of the rotundity of the Earth, we must be content with the names of those who attempted its *measurement*, well knowing that they must have been acquainted with its true form.

Before attempting to explain how celestial distances are determined, it may not be entirely superfluous to briefly refer to the means employed to measure distances on the Earth. Everyone knows that to measure anything, is simply to compare it with something else well-known. Thus, we say, for example, that a front of a house or lot, is sixteen feet, comparing it with the length of a well-known measure of our body, taken as a unit of measure; and, in the same manner, we say that the line A Fig. 1 is twelve inches, which means that it is twelve times as long as the line B, or that the latter is contained, as a unit of measure, twelve times in the former. For our purposes this evening, it is also necessary to understand how the difference of direction, or the divergence of two lines, called their angle, is measured. Mathematicians have also found that if they know the length of one side, and the size of two of the angles, they can find all the sides and the remaining angle of any triangle.

History informs us that Eratosthenes, a Greek mathematician and astronomer, born at Cyrene, in Africa, B. C., 276, called by Ptolemy Euergetes to the charge of the Alexandrian library, which contained all the Phœnician, Chaldaic, Egyptian and Greek learning of the time, first wrestled with the problem of measuring the Earth. Accepting the theory of the globular form of the Earth, he reasoned that if he could determine the length of one degree, he could measure the distance through and around the Earth. He knew that at Syene (the modern Assouan) the Sun was vertical at noon in the summer solstice, while at Alexandria, at the same moment, it was below the zenith by the fiftieth part of a circumference. Neglecting the solar parallax, and ignoring the difference in longitude, if, indeed, he knew that there was any, he concluded that the distance from Alexandria to Syene is the fiftieth part of the circumference of the Earth. This distance he estimated at 5,000 stadia, which gives 250,000 stadia for the circumference, a result containing an error of some importance, yet showing a wonderful degree of knowledge for that age.

We will now endeavor to show how we may find the length of a degree, and hence the size of the Earth, on this same principle. Let P, in figure 6, represent an observer at the North Pole, A the centre of the earth, H I the plane of the horizon at the North Pole, and Z a star that is directly overhead, say the North Star; this star is then said to be in the zenith and a line from it to the observer at P is perpendicular to the plane of his horizon; *i. e.*, at right angles with it. Now, if an observer at, say, Philadelphia, in latitude 40°, observes this same star, he will see it, because of the great distance, in a line parallel with the observer at P but not in the zenith, that is, not immediately overhead. The line from the star S to the observer at O will form an angle with a line perpendicular to the plane of his horizon equal to as many degrees as he is removed from the North Pole, in this case 50°.

We thus find that for every degree south that the observer is removed, he finds a change in the elevation of the North Star, of one degree, hence if he observes how far north or south, in miles, he travels to produce a change of one degree in the elevation of the star, he will know the length of a degree in miles. Multiplying this by 360 will give him the circumference of the Earth, and dividing this by 3.1416 will give him the diameter and the product of the diameter and the circumference will give him the entire surface of the Earth. Half the diameter is called the radius, and having found this, we are now prepared to find the distance to our nearest neighbor the Moon.

Before passing to this subject, however, I will state briefly that a difference of opinion between Sir Isaac Newton and certain French *savants*, in regard to the shape of the Earth—Newton having announced, as the result of his studies in natural philosophy, that it is flattened towards the poles, making it an oblate spheroid, while they, on the other hand, maintained, as the result of actual measurements of an arc of a meridian made by Picard La Hire and Cassini, that it is a prolate spheroid—led to extended measurements of meridians by the French and other governments, which conclusively proves that Newton was right. About one-fourth of the circumference of the Earth has now been actually measured.

The first historical measurement of the distance to the Moon which has come down to us, was attempted by Hipparchus, the "Patriarch of Astronomy," born at Nicea in Bithynia, about 200 B. C. By observing that eclipses of the Sun do not appear to be of the same extent everywhere on the surface of the Earth, he learned that the parallax of the Moon must be large enough to admit of measurement. With the imperfect instruments at his command, however, his results are of course wide of the mark, but his method was correct in principle.

Aristarchus of Samos, a Greek astronomer, who flourished about 270 B. C., who first maintained that the Earth revolves around the Sun—for which opinion some thought him guilty of impiety—attempted to find the distance to the Sun by observations on the Moon, but owing to his observations with the naked eye, and to the fact that the illuminated side is not sufficiently sharply defined for such minute calculations, he was not successful. Ptolemy, who flourished at Alexandria in the second century A. D., next attempted it, though he probably used the method discovered by Hipparchus, namely calculations based on the shadow of the Earth at the time of an eclipse of the Moon. In this manner he obtained a distance fifteen times too large.

So far as I know, Kepler, born in Wurtemberg, 1571, first predicted transits of Venus, namely that of 1631 which occurred during the night, and hence could not be observed, and that of 1761. Horrox, born near Liverpool about 1616, a poor curate of Hoole, predicted and observed that of 1639, watching for more than 24 hours previous to the time at which he had calculated that it would take place, so as to be sure not to miss the opportunity on account of possible errors in his calculations. In 1725, Dr. Halley, born near London in 1656, explained a method of finding the distance to the Sun by observations made on a transit of Venus, and the next one occurring in 1761 and 1769, the problem to be solved was deemed so important that the governments of France, England and Russia sent expeditions to various parts of the Earth to secure observations. It was while engaged in this business that the celebrated Captain Cook lost his life on one of the Sandwhich Islands. Le Gentil went to India to observe the transit of 1761, but by detentions on the voyage he arrived too late. He waited the eight years required for the next transit, and was then disappointed by the passage of a cloud over the sun at the critical time. This transit was observed by David Rittenhouse, of Germantown, one of Pennsylvania's self-taught mathematicians.

From this transit of Venus, the distance to the Sun was found to be 95,000,000 of miles. This it is now believed is too great owing to an error in the calculations. Independent observations made on the planet Mars gave a smaller distance. Great preparations were therefore made for the transit of 1874, involving an expenditure of probably a million dollars. The United States took a prominent part; and stations were occupied in Siberia, China, Japan, the Sanwich Islands, northern India, Persia, Turkestan and Egypt, in the Northern Hemisphere, and at a number of islands in the Indian and Southern oceans, from Kerguelen on the east to Chatham Island and New Caledonia on the west, Australia, Tasmania, and New Zealand being also occupied in force. The distance found was 92,000,000 of miles, trifling reduction of 3,000,000 miles on the previous figures.

The next transit of Venus will occur December 6, 1882, and is naturally looked forward to with great interest. Mr. Proctor will probably be charged with the duty of making preparations and arrangements for its observation, at least so far as England is concerned, where he will, ere long, probably be appointed Astronomer Royal.

And now taking leave of beautiful Venus let us address ourselves to the method of finding the distance of the fixed star. It is simply the problem of the triangle over again, but this time our unit of measure is twice the distance of the Sun or 194,000,000 of miles. These calculations give for our nearest neighbor the star Alpha Centauri 224,000 times the distance from the Earth to the Sun, or 3½ light years; that is, it would take light which reaches us in a little more than 8 minutes from the Sun, 3½ years to reach us from Alpha Centauri.

Thus the astronomer, when he conceives a distance in the solar system, must make the radius of the Earth his shortest unit, and when he attempts to go beyond the Sun and the planets, the shortest division on his measuring line must be the diameter of the Earth's orbit; and even then he will be borne onward so far not on the wings of imagination, but of mathematics that this enormous distance has vanished to a point. Even then he has only reached the nearest fixed star, and of course has only just entered upon the outer limit of creation. He must prepare himself for a still loftier flight. He must reject the diameter of the Earth's orbit as the unit of his measurements, because too short, and take as his standard the passage of light, at the rate of two hundred thousand miles per second. With that speed he can go on, until his mind has reckoned up six thousand years of seconds and he will reach fixed stars whose light, leaving it source at the creation of man, has not yet arrived at the earth.

Overwhelmed with the immensity of the works of God, he looks wistfully forward to the time when the Christian philosopher shall be permitted to resume the study of science in a future world, with powers of investigation enlarged and clarified, and all obstacles removed; when to trace out the shores of that shoreless sea, to measure its now measureless extent, and to fathom its now unfathomable depths, will be the noble and the joyous work of eternal ages.