THE TRANSIT OF VENUS.
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THE TRANSIT OF VENUS.

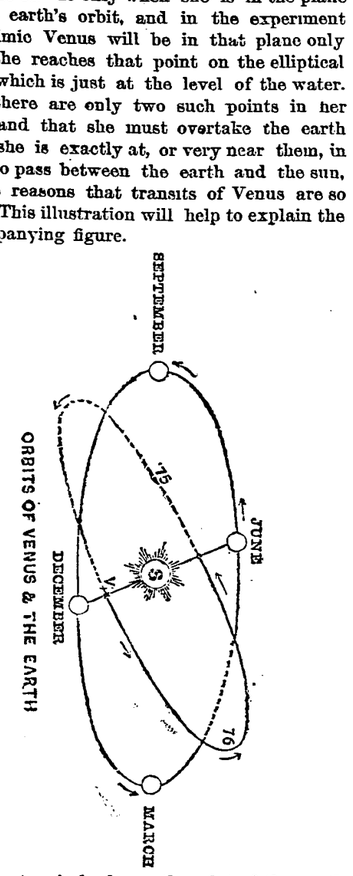
IMPORTANCE OF TO-NIGHT'S EVENT.

WHY TRANSITS ARE SO RARE, AND HOW THEY ARE FORETOLD—HOW THE TRANSIT OF 1874 WILL BE UTILIZED—THE PREPARATIONS BY DIFFERENT NATIONS—WHAT THE ANCIENTS THOUGHT.

Seven minutes before 9 o'clock to-night, an observer stationed anywhere upon the earth where it is then day, will, by looking under suitable conditions, see a small black spot creep on the upper left-hand edge of the sun's disk, and continue, for rather more than four hours, to describe a diagonal line across it, and then disappear. The phenomenon cannot be seen at all with the naked eye, and even when seen with suitable instruments, it will, except for the knowledge that two celestial bodies are concerned, appear scarcely more imposing than the march of a house-fly across a dinner-plate. Yet millions of dollars have been spent in preparations to observe this apparently insignificant event with an exactness never before applied by human art, and to-night hundreds of skilled astronomers, scattered over about seventy stations, widely scattered over the surface of the globe, will turn their instruments toward the sun, inspired with a full conviction that the results of this observation of the transit of Venus will more than repay their large expenditure of labor and money. What adequate return do they expect? A true man of science will hardly discuss the question. To him knowledge is its own reward, and it is enough that he is about to learn something he does not know. But fortunately a more practical answer can be given as well as demanded. It is expected that after the transit, and by its aid, a perfect map of the solar system can be made. It is true that a very well-appearing map can already be laid down on paper. Close observation of the revolutions of the planets, and the application of geometrical principles, have enabled astronomers to map out the orbit of every planet. And, furthermore, according to what is known as Kepler's third law, they can map out these orbits in their exact relations to each other, for the law gives the relative distances of two planets from the sun, when we know the relation between their periods of revolution. This law, the discovery of which is one of the wonders of human achievement, and which cost Kepler half a lifetime of laborious study, is very simple in its application, and is very important in connection with this transit. It may be thus stated: Square the number of years taken by a planet to go around the sun; the result will give a first number. Then find a second number the cube of which is equal to the first number. This second number will express the planet's distance from the sun, that of the earth being called one. To take an example: Jupiter, as astronomers know by observation, takes about eleven years to go around the sun. By squaring eleven we get 121 for a first number. Then by trial we find that the cube of 5 is almost equal to 121. Five, then, is the second number, and it will express Jupiter's distance from the sun when that of the earth is called one. Hence we are right in saying that Jupiter is about five times as far from the sun as the earth is, and if the exact number of years had been used the exact distance would have been got. And this method may manifestly be applied to all the other planets. Thus it is that astronomers are able to draw a celestial map, in which the actual elliptic orbits would be expressed so exactly that no microscope could detect an error. But if this is so what more can be wanted? The unsupplied wants a fatal defect—the map has no scale. And so long as a scale is wanting it is manifestly impossible to say how much actual distance is measured by an inch upon the map, and the case is even worse than this, for the celestial map, instead of having no scale, has an erroneous one. But if now, since the relations of the map are so accurate, the actual number of miles between any two points can be obtained, the astronomers will then plainly know what an inch on the map stands for in actual distance, and thus will be supplied the lacking scale. Thus it is seen why the coming transit is so important. It is expected not only to decide the distance from the earth to the sun, but also, and by means of this distance, to furnish the means for calculating all the dimensions of the solar system. This is the main benefit which is expected to be derived from the transit. But there are many incidental benefits also which are not entirely beneath notice. The science of optics will, it is thought, be benefitted in no small degree, and the accuracy of the science of navigation will be greatly increased. For not only will the longitude of many specific stations be determined with, humanly speaking, perfect exactness, but the knowledge of the exact distances of the heavenly bodies will enable the marine tables to be corrected, and will enable vessels to sail by "dead reckoning," that is without any direct observation of the heavenly bodies, with a confidence and accuracy at present merely hoped for. Again, it cannot be doubted but that some among the host of scientific men whom the various expeditions will scatter to the ends of the known world, will make valuable meteorological and magnetic observations; and geologists, botanists, and naturalists are specially appointed to accompany some of the English expeditions. There then can be but little doubt that science in general, as well as astronomy in particular, will greatly profit by the transit of Venus. But why, it may reasonably be asked, is the transit of Venus—a celestial phenomenon so rare that it only occurs twice in each century—singled out to supply this information? It is because Venus is the planet nearest to the earth, and because the difficulty of measurement is so much increased by the greater distances of the others as to be nearly insuperable.

WHY TRANSITS ARE SO RARE.

It takes the earth 365 days to complete its journey around the sun, while Venus completes her revolution in 224. Since, then, her time of revolution is so much shorter than the earth's, she must overtake it sometimes, and this she does in a period of 584 days, or about nineteen months. But how is it that she can overtake the earth once every nineteen months for 120 years, or some seventy-five times in all, and yet never once come between the earth and the sun in all that century? The explanation is very simple. If Venus and the earth traveled about the sun on the same level, that is, if their orbits were in the same plane, just so surely as Venus overtook the earth she would pass between it and the sun, and there would be a transit of Venus every nineteen months instead of two in every century. But they do not travel about the sun on the same level. The ellipse in which Venus travels is so inclined to the earth's path that one-half lies above it and one-half below it. A representation of this may easily be made by cutting a piece of board into an ellipse and then plunging it for half its length into the centre of a circular basin of water. The circumference of the basin would represent the earth's orbit, and the level surface of the water would represent its plane. And as the rim of the elliptical board represents the path of Venus, it is clear that that portion of her path above the surface of the water is above the plane of the earth's orbit, that that portion below the surface of the water is below the plane of the earth's orbit. Now it needs no demonstration to show that Venus may be at any point of her orbit when she overtakes the earth. But whether she is above the earth or below it, it is equally impossible that she should come between it and the sun. That she can do only when she is in the plane of the earth's orbit, and in the experiment the mimic Venus will be in that plane only when she reaches that point on the elliptical board which is just at the level of the water. That there are only two such points in her orbit, and that she must overtake the earth when she is exactly at, or very near them, in order to pass between the earth and the sun, are the reasons that transits of Venus are so rare. This illustration will help to explain the accompanying figure.



The outer circle shows the orbit of the earth, and her positions in March, June, September, and December. The ellipse lying within this, and inclined to it at an angle of the one hundredth part of a circle, represents the orbit of Venus. Now it can readily be seen how, if the planet overtook the earth between June and December, she would seem to be below the line joining it and the sun, and if between December and the following June, above it. And it can also be seen how, when the earth and Venus are both on the line which the planes of the two orbits make by cutting each other, (represented in the figure by the line joining the points reached by the earth in every June and December,) she must pass between the earth and the sun, and thus cause the phenomenon known as a transit of Venus.

HOW TRANSITS ARE FORETOLD.

The rarity of these transits, of course, adds nothing to the difficulty of their prediction. They are foretold in the same manner as eclipses, and the periods of their occurrence depend upon the relative times of revolution of the earth and Venus, combined with the inclination of the planes of the two orbits to each other. The figure just referred to will help to an understanding of this also. The earth, we will suppose, is at the point in its orbit marked "December," and Venus is at the point in its orbit marked V. In other words, the transit of 1874 is just occurring. In one year the earth will return to exactly the same point in its orbit. But Venus completes its revolution in 224 days. Therefore, when the earth in 365 days has returned to the point marked December, Venus will have not only reached V, but will have passed as much beyond it as to the point marked '75, which is her position in that year. In another 365 days the earth will again reach the point marked December. Venus, too, has in the same period again reached V, but as before, she has passed beyond it, and is now at the point marked '76, in which year, as also in '75, there can be no transit, for reasons already explained. And this goes on for eight years, a period of time which is so nearly equal to thirteen of Venus' years, meaning thereby her time of revolution about the sun, that in 1882 both Venus and the earth are almost in the same positions they occupied in 1874, and there is consequently another transit. If they were in exactly the same positions, of course, there would be a transit every eight years. But the departure from perfect equality between eight revolutions of the earth and thirteen of Venus, although not sufficient to prevent a transit in a single period of eight years, will be doubled in sixteen years, and then no transit is possible. And each year thereafter this departure is increased, until finally it is equal to a whole revolution of Venus. This occurs after 235 years, and then there is another transit. Thus it will be seen that transits occur at the December station of the earth at intervals of eight and 235 years. Eight years from this December there will be another transit, and there was one in December, 1639—235 years ago. But it will not be 235 years from 1882 before there is another transit, for it will be remembered that transits may also occur at the point in the earth's orbit marked June. During the 235 years from December, 1882, on June 7, 2,004, there will be a transit, and another eight years after it. Then it will be 235 years from that last date before there can be another June transit, and in the mean time the period for a December transit will have again arrived. Thus is explained, it is hoped, with an approach to clearness, how transits are foretold, and also why it is that they occur in pairs at the mystic period of eight years.

Supposing, now, that by these methods it is known that a transit is about to occur. How is it to be utilized in ascertaining the sun's distance from the earth? There are several methods in use among astronomers for this purpose, but before describing them it will be necessary to thoroughly explain

WHAT PARALLAX IS.

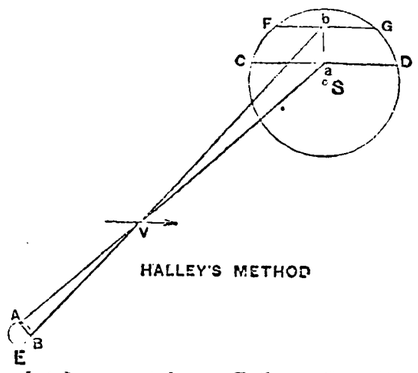
This is about the only scientific term with which the reader need be troubled, and it cannot be got rid of, because it is the key to the whole matter. Once having mastered the mystery of the parallax the rest follows easily, and, therefore, upon the threshold of this sketch, an attempt will be made to enable the reader to get, as he very easily may, a clear idea of what an astronomer means by the parallax of a heavenly body. Going to our Webster, we find that parallax is, in astronomy, "the change of place in a heavenly body in consequence of being viewed from different points." To an astronomer, who knows beforehand what parallax is, the definition is perfectly clear, but to one in search of information the explanation is nearly unintelligible. An illustration may help the matter. Let a man assume such a position with reference to some fixed object that a line drawn from him through it will point exactly north. Now, let him change his position to the westward. A line drawn from him to the observed object now will no longer point north but in some other direction, say north-east. This change in the direction of the object is the effect of parallax. It is an apparent change of place in consequence of being viewed from different points. A single other illustration will suffice. Let any small object, as a lead pencil, be held in front of the eyes, and at a convenient distance from them for seeing it. Now close the left eye and note upon the opposite wall some fixed point covered by the pencil. Then, closing the right eye, and opening the left, also note upon the wall some fixed point covered by the pencil when thus looked at. All this time the pencil has remained unmoved, and yet it will be found to have shifted its apparent position on the wall to a degree which will astonish any one who has never tried the simple experiment. And this change of direction in consequence of being viewed from different points is the parallax of the pencil. The experiment may seem a rude one, and yet observe how exactly it represents the astronomical phenomenon now being discussed. For the head, the earth may be substituted; for the eyes, two observers situated as far apart on the earth's surface as they can get; for the wall, the sun's face; for the pencil, Venus, and for the parallax of the pencil, the parallax of Venus. As the observer's eyes in the experiment with the pencil are on a horizontal line, of course the change in the position of the pencil occurs on a horizontal line also. But it is very easy to suppose that the eyes are in a vertical position, as if the observer were lying upon his side, and in that case the change of position would also be in a vertical line, which is the same as saying that parallax may be a change of vertical as well as of horizontal position. To give a single example: In the figure, illustrating De Lisle's method, an observer at A would see C in in the direction A C, and an observer at B would see C in the direction B C. The difference of these directions is the angle A C B, which is the parallax of C, as seen from the points A B.

THE RELATION OF PARALLAX TO DISTANCE.

Besides keeping to an understanding of what parallax is, the experiment with the pencil will also help us to understand how the ascertainment of a body's parallax gives its distance. Thus let the experiment be tried several times, and at different distances from the wall. It will be found that the change of direction is due to the distance between the eyes, but that this being constant, the amount of the pencil's displacement on the wall is due only to its distance from it, and that, consequently, as the distance varies the amount of displacement varies also. Now we are prepared to say how the distance of the wall can be calculated without going to it. For as the apparent motion of the pencil on the wall is so connected with its distance from it as that the one depends upon the other, tables may clearly be prepared from which, when one is known, the other may be found. Such are the trigonometrical tables in common use, which will always give the distance exactly when the change of direction or of place, or, in other words, the parallax, is known exactly. At the risk of repetition it is again stated that finding an object's distance and finding its parallax are convertible terms. When the latter is large it is easily got, and implies a small distance. But when minute it is found with difficulty, and implies great distance. The fixed stars, for instance, are so far from the earth that they have no appreciable parallax. And it may be added that the sun's horizontal parallax, as the astronomers call its change of direction as seen by two observers separated by half the diameter of the earth, is almost immeasurably small. It is less, whatever it is, than an angle of 9″.5, or than that angle which a human hair would fill at a distance of five feet from the eye. It was an error of one-thirtieth of this last—an error, less, that is, than a literal hair's breadth seen fifty yards off—which caused the mistake of 3,000,000 miles now known to have been made in measuring the sun's distance in 1769.

HALLEY'S METHOD.

Having premised thus much, we are now in a condition to consider how the transit of Venus may be made available for determining the distance of the sun from the earth. It has been seen that the parallax of the sun cannot be used for this purpose because of its immeasurable smallness when directly obtained from the earth. Dr. Halley's method enables the astronomer to employ, instead of the parallax of the sun, the parallax of Venus when nearest the earth, and consequently when her parallax is greatest. In fact, the distance from the earth to Venus is only about one-quarter as much as that to the sun, and therefore her parallax is almost four times as large as his. Let it be assumed, then, that a transit of Venus across the sun's disk is actually under inspection from the earth. The adjoining figure will represent all the different relations which are necessary to the solution of the problem.



HALLEY'S METHOD

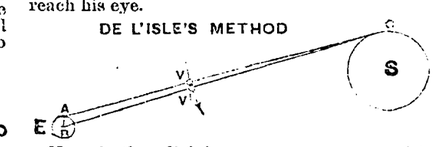
Let S represent the sun, E, the earth, and V, Venus, supposed to be moving in her orbit at V between the sun and the earth. Let A and B represent the positions of two observers watching the phenomenon from the earth, A being a point near the North Pole, and B a point near the South Pole. It is evident that to these two observers the transit will appear to take place on different lines. To the observer at A, Venus will seem to cross the sun's disk on the line CD, while to the observer at B she would seem to cross it on the line FG. And *ab*, the distance between the lines CD and FG, measures the angle *a*V*b*, which is equal to the angle AVB, and the angle AVB is the parallax of Venus as seen from the stations A B on the earth. The problem before us is to see how the line *ab* will help us to the distance of the earth from the sun. Now, according to the principles of the geometrical relations of triangles we have the proportion *a*V: AV:: *ab*: AB, which is equivalent to saying that the line *ab* must be just as much longer than the line AB as the line *a*V is longer than the line AV. But we know from Kepler's third rule that AV must be taken 1 and 3-7 times to equal *a*V, and we may know, by measurement, exactly how many miles, feet and inches apart are the stations A and B on the earth's surface. Consequently, we know that if A and B is taken 1 and 3-7 times, the product will equal *ab*. The exact length in miles of *ab* on the sun's surface has, therefore, been obtained, and the first step in the solution of the problem has been taken. It only remains to find out if possible what part *ab* is of the entire diameter of the sun, and then we should know this diameter in miles. We do know the angular diameter of the sun; that is, we know the angle made by two lines drawn from the eye to the extremities of the sun's diameter is equal to 32′. The radius of the sun is therefore 16′. If the observer, then, at A had timed with great precision the ingress of the planet at C and its egress at D, he would know the time occupied by Venus in traversing the line C D. Then, knowing the rate at which the earth and Venus move in their orbits in minutes, not in miles, he can tell the exact length of CD in minutes. In like manner the length of FG can be determined in minutes. From these lengths it is easy for a geometrician to derive the length of *ab*, the distance between the two lines, in minutes. But we already know *ab* in miles, and from these two values of the same quantity we can easily ascertain how many miles are due to each second of arc at the distance of the sun. It is about 450 miles. Hence the angle subtended by the earth's radius, which is called the parallax of the sun, must be the quotient of 450 miles contained in the earth's radius, namely something rather larger than 8″.5, corresponding, according to Encke, to a distance of about 95,274,000 miles. Such is substantially, though not exactly, the process by which the sun's parallax, and therefore the sun's distance, is obtained from the transit of Venus according to Halley's method. There are numberless considerations connected with the process which cannot be here explained. It will of course be understood that such complications as arise from the elliptical rather than circular form of the orbits, the real inequality of the motion of Venus and the earth in their orbits, the fact of the earth's being constantly turning and changing the observers' positions whether they will or no, and many other similar details, can only be mentioned here by way of suggesting how excessively intricate are the actual computations which the astronomer must make. It was said that the distance of the earth was "about" 95,274,000 miles. It will of course be understood that the inexactness of expression arises from the fact that the sun's parallax is known to be only "about" 8″.5. After the transit, the astronomers hope to be able to say exactly what the parallax is, and then they can compute the sun's distance exactly. At present they only know that 95,274,000 of miles is almost three per cent. too large to express the sun's true distance from the earth.

Although the explanation of Halley's method has been made as simple as possible, it is quite likely that the necessity of close reference to the figure will perplex those not recently accustomed to geometrical discussions. A demonstration may be given which is substantially the same as the above, and which yet requires no figure. It is clear that in the case of two observers at different stations, Venus will appear to describe two paths in her transit across the sun. But when one of these stations is in the far north and the other in the far south, one of these paths, which are both chords of the sun, will be further from the sun's centre, and consequently shorter, than the other. The duration of the transit, so far as this effect is concerned, is directly proportioned to the length of the chord traced out by Venus. Thus from observation we obtain the lengths of these chords; and by geometry we can deduce the least distance between the centres of the sun and Venus at each of the two stations, and hence we can determine the sun's parallax. In leaving this method it may be said that its chief excellence is its great accuracy, which consists in this, that in one second of time Venus moves over only about 0″.02, and if even an error of a whole second is made in noting the time of ingress or of egress, the sun's parallax is measured with an error of no more than .02 of a second of arc. But it has its disadvantages also, among which are the necessity of observing the whole transit, and these have led the English astronomers to use this year

DE LISLE'S METHOD,

Which is far simpler than Halley's. It takes advantage of the fact that the ingress of Venus upon the sun will take place later when seen from some parts of the earth than from others, and it uses the orbit of Venus as a vast protractor for measuring small angles. It will be best to precede the detailed exposition of the method by an illustration. If we suppose a person looking at a remote object—say a lighted window—from a distance of half a mile or rather more, the distance between his eyes bears nearly the same relation to that of the light from them that the distance between any two stations practically usable on the earth does to that of the sun. Accordingly, the difficulty of obtaining the sun's parallax without moving from off the earth is quite comparable to that the observer would experience in trying to measure the distance of the light without moving from his place. To prevent the problem being quite incapable of solution, he may be granted all the help the astronomer will derive from the transit of Venus. Her motion may be represented by a car moving at a uniform rate, on a circular track, between the light and the observer. If the car pass across the light from left to right, (as Venus crosses the sun,) it will, of course, cut off the observer's view of the left side of the window from the left eye first, and if the motion of the car is slow enough, we may suppose him to note the exact time from that instant before the sight of the same point by the right eye is intercepted. Now, if he knows from previous watching how long it takes the car to make a whole circuit of 360°, he can tell from his watch just what fraction of 360° it went over in passing, or in its shadow passing, from one eye to the other; and this certain fraction of 360° is the measure of the angle which the distance between his eyes would appear to subtend as seen from the light. But that is the parallax of the light, and it gives him its distance at once when the distance between the eyes—the base line—is known. Now to apply this on a grander scale. We know that the earth revolves about the sun in 365 days, and Venus in 224. But it will be simpler to take no account of the earth's revolution, but to suppose our globe to stand still with reference to Venus, in which case the revolution of Venus relatively to the earth, the synodical revolution, in astronomical language, is 584 days. Now, as Venus passes through 360° in 584 days she, of course, passes through 1-584 of 360° in one day, and by dividing that quotient by the number of minutes in a day we can get the length of her path in one minute, and it is found to be about 1″.54 of arc. That is the rate at which the shadow of Venus (could she throw one so far) would pass over the earth as seen from the sun. It is needless to say that the path of the shadow of Venus across the earth cannot be observed, for the light of the sun will blot it out, but the instant at which an observer has his view of the edge of the sun interrupted by Venus is clearly the instant at which this imperceptible shadow will reach his eye.

DE L'ISLE'S METHOD



Now, in the adjoining cut we are supposed to be lifted above the sun, earth, and Venus, and to look down upon what occurs as from an immense balloon. S represents the sun, V Venus, and E the earth, upon which A is supposed to be the position of an observer upon the extreme left or eastern side of the globe, and B the position of an observer at the centre of the globe. C represents that point upon the rim of the sun's disk at which Venus appears to begin her transit, and the angle at C is the angle which the earth's semi-diameter would fill to an eye at the sun, or, in other words, it is the solar parallax, for it represents the difference in the directions in which the sun would be seen by the two observers. Now, suppose the observer at A has his view of C interrupted by V coming into line with it at exactly 9 o'clock. The observer at B can still see C clearly, but in say 5¾ minutes Venus has progressed to V′, and then B has his view of C interrupted by the interposition of the planet. But since, as has been seen, Venus passes over 1″.54 in each minute, in 5¾ minutes she has passed over 8″.85, and this angle represents the difference of directions in which the sun will be seen by the observers at A and B. And the astronomer, on referring to his solar tables, will find that such a difference of direction could only be caused by an object nearly 92,000,000 miles away. It is hoped that the transit will show how much the angle 8″.85 must be changed in value to insure its absolute correctness, and then the distance can also be obtained from the solar tables with equal exactness. It only remains to be added that in practice the observers need not be placed at the extreme edge and centre of the earth, since the effect of distances greater or less than half a diameter can be easily allowed for. But this is only one of the many complicating circumstances which simplicity demanded should be omitted.

THE PHOTOGRAPHIC AND HELIOMETRIC METHODS.

Two methods remain to be described, and the four, with their variations, will include all the methods, ancient and modern, by which the transit of Venus is utilized in obtaining the sun's distance. The photographic method appeals largely to our national pride, for it was originally proposed by Mr. L. M. Rutherfurd, of this City, and to it the attention of the American observers has been principally devoted. Some idea has been given of the almost inconceivable delicacy of the measurements which are to be made, and the difficulty is a thousand-fold enhanced by the necessity of making them instantly, at the penalty of losing, perhaps, the only chance in a century. But suppose a large number of instantaneous photographs of the sun with Venus on its face are taken. It is easy to see that by combining the photographs which represent the different positions of Venus during the transit, a perfectly exact map of the apparent pathway may be made. Here we have something that can be taken home and measured at leisure, for the sensitive plate is an observer which does not get flurried, is perfectly impartial, and whose observations are permanently recorded. Of course, it is impossible to photograph the sun directly, and if the lens of a common telescope were used to produce the image of the sun upon the sensitive plate the picture would be too small for accurate measurement. Mr. Rutherfurd avoids the difficulty by using a telescope nearly forty feet in length. So long a telescope is far too unwieldy to point at the sun. It is therefore fixed in a horizontal position, and the rays of the sun are thrown through it by a mirror. An image of the sun about four inches in diameter is thus produced. The mirror is simply a piece of finely polished glass, without any silvering whatever. It only reflects about one-twentieth of the sun's light, but so intense are his rays that his picture can be taken in less than the tenth of a second. The most difficult operation in the construction of the apparatus was the polishing of the mirror, for if it should deviate but the one hundred thousandth of an inch from perfect flatness the error would be fatal. The scale of the picture is determined by actually measuring the distance between the object glass and the photograph plate.

The exact measurement of the distances of Venus' edges from the opposite edges of the sun is another way of obtaining the distance between the centres of the sun and planets. The heliometric method consists in measuring these distances directly with the heliometer, an instrument which cannot be had in this country at all, and which English astronomers describe as being both complex in construction and difficult to use. Further description of it may therefore be spared, except to say that it furnishes two images of the sun, and gives the means for measuring them exactly according to scale. This instrument will be used by the Germans, Russians, and Lord Lindsay, an English nobleman who fits out a private expedition, and not at all by the Americans, English, or French.

Having now completed a review of the methods by which Venus' transit will be utilized, it will be suitable to examine the

DIFFICULTIES TO BE ENCOUNTERED.

by the observers. It may be premised that an astonishing degree of accuracy was long ago obtained. The angle which represents the error Kepler found in the sun's parallax as then known would correspond to that filled by the page of an ordinary octavo volume at the distance of half a mile from the eye, and the error now admitted as probable by Prof. Newcomb, a great American authority on such matters, would correspond to that filled by the edge of the same leaf at the same distance. The whole angle of the parallax which is to be measured only equals 8″ or 9″, and its value is already known to within one-tenth of a second. What is desired is to make the measurement exact to within a hundredth of a second of arc. An example will give an idea of the excessive smallness of these angles. A second of arc is the angle filled by a silver half dollar at the distance of nearly four miles. A tenth of a second of arc is the angle subtended by the same coin at the distance of forty miles, and the error in the parallax is probably not more than a tenth of a second. A hundredth of a second, which is the degree of accuracy aimed at, is equal only to the angle filled by a human hair at the distance of a mile. But there are other obstacles to be encountered besides the excessive accuracy of the necessary measurements. Observations upon the sun are attended with peculiar difficulties. Its surface, instead of being a perfect globe, which would present to the earth the appearance of a disk with a sharply-defined outline, is composed of gases in a fearful state of agitation and combustion. The edges of the disk are ragged and irregular, and it is therefore difficult to tell the precise instant when the first contact of Venus with the sun takes place. Moreover, it is impossible to see Venus until after the contact has actually begun, because her dark side is turned toward the earth. These are difficulties attending the "external contacts," as are called those phases of the transit when Venus is just touching the sun, but is yet wholly outside of it, the "internal contacts" being those phases when Venus is just wholly inside the sun's ring, and is about to separate her edges from his. And, like the external contacts a peculiar difficulty, known as the "black drop," is found to attend the determination of the precise moment of internal contact. The black drop is an optical illusion by which, when it would seem that Venus ought to be clear of the sun's edge, she yet appears to cling to it and to pull it out of shape, something as a drop of ink distorts the point of a pen in falling from it. It can readily be seen how such an appearance as this would disconcert those who were expecting, in 1769, that the edge of Venus and the edge of the sun would appear as sharply defined as the edges of two circular coins brought in contact with each other. But the difficulties attending the observations of both internal and external contacts are now provided for. For determining the exact instant of the latter, the spectroscope will be used, according to a plan which Prof. Young conceived during his observation of the eclipse of 1869. It is well known that if the spectroscope be turned upon the body of the sun a spectrum is furnished which is crossed by black lines. But if it be turned upon the gaseous envelope which surrounds the sun a spectrum of bright lines is seen, which have all been located and named with great exactness. If now the spectroscope is so arranged that no light can reach it except from that portion of the gaseous envelope which Venus must cross the instant before she enters upon the true disk of the sun, she must in her passage obstruct that light and constantly blot out the bright lines of the spectrum. The moment of their total extinguishment must be the moment of external contact. The phenomenon of the black drop will also cause less difficulty in estimating the true time of internal contact now than formerly, partly because it is expected, and partly because its nature is better understood. It was formerly thought to be due to the atmosphere of Venus, but it is now known to be caused by irradiation, in the same way that a very thin platinum wire, when heated to an intense degree by electricity, seems to be about the thickness of a pencil to those who are regarding it from a distance. In order to accustom the observers to this distortion of Venus' disk by the black drop, an artificial planet was made to move by clock-work over an artificial representation of a portion of the sun's disk. The apparatus was set up at a distance of half a mile from the observers in order to give the effect due to atmospheric undulations. This instrument has both thrown a great deal of light on the question of the black drop and has also given the observers much preliminary practice in the observations they will have to make on the day of the transit. Many other difficulties which embarrassed the observers of the last transit will be obviated by the improvements of modern astronomy. Among them may be mentioned the following: The instruments will be of better quality, and will give much more clearly-defined images; the chronograph will help to measure time to hundredths of a second as easily and accurately as tenths could before be measured, and finally, not to speak of lesser improvements, the means for obtaining the exact longitude of the stations of the different observers are much improved, and in some cases will be almost perfect, owing to the use of the telegraph.

PREPARATIONS WHICH HAVE BEEN MADE.

Having thus outlined what the astronomers expect to see this evening, and how they will make use of it, with a view rather to clearness of apprehension by the reader than to any approach to scientific accuracy, it will be appropriate to give some idea of the preparations which have been made for the occasion by the various nations of the world. The English were the first to take action in the matter. As far back as 1857, Sir George Airy, Astronomer Royal, had sketched a general plan of operations, and in 1870 his instruments were in process of construction. In 1869, the Russians and Prussians took preliminary measures, and it was not until the Naval Appropriation bill of 1871 was passed that our own Government took any official notice of the transit. Then a commission was appointed, consisting of the Superintendent and two professors of the Naval Observatory, the Superintendent of the Coast Survey, and the President of the National Academy of Science, to make all necessary preparations, and an appropriation of $150,000 was made for this purpose, besides giving the services of naval vessels for the transportation of the observers and their stores and instruments to the places selected. The selection of the places of observation was a matter which called for the exercise of a high degree of judgment. They must be so geographically situated as to make it possible to see the transit; they must be chosen with a view to favorable atmospheric conditions; they must be on solid land, for the observers cannot work on shipboard. And as the recent correspondence of THE TIMES has shown, even when the places chosen satisfy all other conditions, it may be impossible to land observers at them, or to subsist them when once landed. All these matters were carefully weighed, and it was determined that of the eight parties which were to be sent from the United States, five should go to southern and three to northern stations. Suitable northern stations were easily found, for the transit will be visible over all of China, Japan, and Northern India, but in the southern hemisphere there was considerable difficulty in choosing stations, as the localities where the transit will be visible are mostly in mid-ocean. The following are the names of the principal American observers and their situation: Wladiwostok, Siberia—Prof. Hall, of the Naval Observatory, assisted by Mr. O. B. Wheeler, of the Lake Survey. Pekin, China—Prof. J. C. Watson, of Ann Arbor. Nagasaki—Prof. G. Davidson, assisted by Mr. O. H. Tittman. The following are the Southern stations: Campbelltown, Tasmania—Capt. Raymond, of the United States Engineers, assisted by Lieut. Tilman. This party failed to make their proposed landing at Crozets on account of stormy weather, and the party were landed on Kerguelen's Island. Hobart Town, Tasmania—Prof. Harkness, of the Naval Observatory, assisted by Mr. L. Waldo, of Columbia College. Kerguelen's Island—Lieut. Commanders Ryan and Train, of the United States Navy. Bluff Harbor, New-Zealand—Prof. C. H. F. Peters, of Hamilton College, New-York, assisted by Lieut. Boss, of the United States Engineers. Chatham Island—Mr. Edwin Smith, assisted by Mr. Scott, both of the Coast Survey. Halley's and the photographic methods will be chiefly used by the Americans. The English chiefs of observers and stations are as follows: Egypt, Capt. C. O. Browne, R. A.; Sandwich Islands, Honolulu, Capt. G. L. Tupman, R. M. A., and Hawaii, Prof. G. Forbes; Rodriguez, Lieut. C. B. Neate, R. N.; Christ Church, New-Zealand, Major H. Palmer, R. E.; Kerguelen's Island, Christmas Harbor, Rev. S. J. Perry, and Port Palliser, Lieut. C. Corbet, R. N. In addition to these, Lord Lindsay fits out a most completely-appointed private expedition to Mauritius, and it is possible that Mr. Proctor will make photographic observations at a station in Northern India. The method generally used by the English is De l' Isle's. Under the lead of M. Dumas the French will occupy stations at the following places, under the charge of the astronomers named in connection with them: Campbell Island, M. Bouquet De La Grye; St. Paul Island, M. Moucher; Pekin, M. Fleuriels; Yokohama, M. Jannsen, and also stations at Tientsin, Sagou, Numea, and Nukahiva, in the Marquesas. The photographic and De l' Isle's method will be used by the French. The Germans, under the superintendence of Dr. Auwers, will use the heliometric method chiefly at the following stations: Chefoo, Kerguelen's Island, Auckland Islands, Mauritius, Ispahan, Aden, and perhaps a station in Japan. The Prussians will also use the heliometer at some twenty-seven Siberian stations, and the whole expedition is in the charge of M. Otto Struve. The Dutch send one expedition to the island of Bourbon, and the Italians send three, about which little is known, and which are equipped with spectroscopes. There being so many stations it is almost impossible that unpropitious clouds will prevent observations at all of them, and as the most amicable interchange of results may be counted upon, it is most likely that this problem will now be solved.

RESULTS OF PREVIOUS TRANSITS AND OTHER METHODS.

In this connection it will not be uninteresting to glance at what has been previously done in discovering the sun's distance. The ancients held the most absurd ideas upon the subject. Herodotus says the sun was thought to be five miles away, and to drift southward, each year, as if retreating from the northern winds. Aristarchus, who flourished about 270 B. C., deduced from measurements of the triangle formed by the sun, earth, and moon, when the latter was exactly half full, that the sun was twenty times more remote than the moon. Ptolemy, from some ancient observations of eclipses, concluded that the solar parallax was 3′, corresponding to a distance of 1,200 semi-diameters of the earth, and this grossly erroneous measurement was accepted as true until the time of Kepler. His discovery of the relative distances of the planets first made possible the application of the transit of Venus to the solution of the problem, and by the aid of his Rudolphine tables he made the first prediction of a transit of Venus, but as it took place after the sun was below the horizon in Europe it was invisible there. After this the matter seems to have dropped from general attention. But Jeremiah Horrox, a young English curate, who had the taste and learning necessary to a successful pursuit of astronomy, suspected that a transit would occur in 1639, although none was foretold, and he acquainted his friend Crabtree, of Manchester, with what he thought upon the subject. These two young men were the only persons who saw the transit of 1639. Horrox prepared himself to observe it by so arranging a telescope as to throw an image of the sun (about six inches in diameter) upon a screen in a darkened room. His calculations indicated that the transit would occur on Nov. 24, (old style,) but he kept watch from the 23d, so as to prevent all disappointment. The 24th was Sunday, but although he knew he was watching for what no man then living could hope to see again, he left his telescope to perform his clerical duties. On his return he went instantly to his darkened room, and there, in his own words, "an opening in the clouds, which rendered the sun distinctly visible, seemed as if Divine Providence encouraged my aspirations, when, oh! most gratifying spectacle, the object of so many earnest wishes, I perceived a new spot of unusual magnitude and perfectly round, which had just entered upon the left limb of the sun." His observations were of great value in correcting the tables of Venus, but his estimate of the distance of the sun at 7,500 diameters of the earth, was necessarily very erroneous, as it was the work of a single observer, and no good result can be obtained, as has been shown, by less than two who are widely separated. But Halley was the first to see clearly what an unequaled opportunity for determining the sun's distance is afforded by a transit of Venus, and in a letter written in 1672, from St. Helena, whither he had been sent by Charles II. to make a catalogue of the stars of the southern hemisphere, he proposed the method which bears his name, but which he knew he could not live to apply. The importance of the transit was, however, impressed upon astronomers by him, and, as the long-expected 5th of June, 1761, approached expeditions were sent out to observe the transit by France, England, Denmark, Sweden, and Russia. But their observations were deprived of all correctness by the black drop, and when an error of one second was hardly expected there was an actual one of twenty or thirty. On returning home and computing their observations the English observers reported a parallax of 8″.5, and the French of 10″.5. These are the extremes of all the observations, and as the corresponding estimates of the sun's distance varied from 88,000,000 to 108,000,000 of miles, it will readily be seen that not much certainty had yet been obtained. But, undismayed, preparations were again made by the various European Governments to observe the transit of 1769. The commencement of this transit was visible in this country, and, under the auspices of the American Philosophical Society, parties of observers were stationed at Norristown, Philadelphia, and Cape Henlopen. The observations they made have the appearance of being very accurate, but they were also very discordant from the European observations. The observations of the several parties in 1769 agreed very well, and seemed to indicate a parallax of about 8″.5, but half a century elapsed before the results were completely worked up. In 1824 Encke undertook the task, and the value of the solar parallax, as reported by him, was 8″.5776, corresponding to the distance so familiar to all who were at school twenty years ago. This value was unquestioned for more than thirty years, but then an error was suspected from the unanimity of the values given by several other methods for calculating the sun's distance. One of them was the aberrations of the moon in its orbit, which Hansen, in 1854, showed could not be accounted for except by supposing that the sun was nearer to the moon than was supposed by about one-thirtieth of its entire distance. Another method was by measuring the velocity of light. Recent experiments made in France by Foucault and Carew have proved that light travels about 185,000 miles in a second, and we know that it consumes 498 seconds in coming to the earth from the sun. This gives a distance of 92,315,000 miles, and a solar parallax of 8″.86. Almost the same result was reached in 1862, when the solar parallax was, with the aid of the planet Mars, found to be 8″.85. From the general accordance of these and various other methods, it is almost a certainty that Encke was wrong, that the solar parallax lies between the limits of 8″.82 and 8″.86, and that the sun's distance is somewhere between 92,200,000 and 92,600,000 miles. This is all that can be said until the results of the transit of 1874 are thoroughly worked up. Individual parties may complete their computation sooner, but it is not probable that the result of any general comparison of observations can be made known much before the year 1876.

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