THE TRANSIT OF VENUS 1874.

With special reference to the importance of determining the true distance of the Sun in connection with Meteorology.

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The title of the present paper may appear at first sight somewhat paradoxical. It may be asked what has the transit of Venus to do with Meteorology? The answer is—the transit of Venus is the best means of procuring the sun's true distance from the earth, and the sun has everything to do with Meteorology. The relation of these subjects to each other appears an interesting question for discussion.

The time appears now to have arrived, since such inestimable additions as spectrum analysis and photography have been applied to the telescope, for the better examination of celestial objects. When this is accomplished, the physical laws which, by the agency of the sun and planets, influence the Meteorology of the earth cannot fail to be better understood.

The study of Astronomy requires mathematical knowledge of the highest order, and its truths are not at all times open to ocular demonstration. But on the other hand, the astounding spectacles in Meteorology, storms with thunder, lightning, &c., could not fail strongly to impress the imagination of man, and lead him to conclude that meteorological phenomena bore directly on his well-being.

But if these two sciences were born at the same time, they are far from having made the same progress. Astronomy has long ago attained a certainty so great, that it is now considered the first of all sciences of observation. Meteorology, on the contrary, is still in its infancy; it requires the application of different laws of physics to particular phenomena. Meteorology, therefore, could make no real progress until the physical sciences were sufficiently advanced, the most important of which for meteorology is electricity, which dates back scarcely a century, and at the present time its operations in nature are but little known; but in whatever way these phenomena offer themselves to the earth, they are analogous with solar physics.

There is no problem in astronomy which has had so much attention paid to it as that which proposes the true parallax of the sun. Different results have been arrived at by different observers over a long space of time, and yet it remains an open question to be determined at the forthcoming transit in December, 1874. The earth's true distance from those powerful solar influences, which in many ways affect its atmosphere is a problem much required to be solved. By this means only can we obtain a more correct knowledge of those physical laws which influence the phenomena observed in our solar system.

The parallax of Venus is known to be almost four times as great as the solar parallax, which causes a very sensible difference between the times that Venus will be seen to pass over the sun by observers situated at different parts of the earth's surface; if the observations are correctly made, the sun's parallax can be determined in this way to a small part of a second, and will furnish an universal standard of astronomical measure for all the planets in the system.

The older astronomers endeavoured to ascertain the sun's distance, or in other words the sun's parallax; but in practice this is a very delicate problem, as the sun's parallax forms a very small angle. Aristarchus of Samos, 260 years B.C., thought that as the centre of the sun,the centre of the moon, and the eye of the observer, form the three summits of a triangle, in which one angle is a right angle when the moon is at a quadrature, or when the light and dark portion of the lunar disc are separated by a perfectly straight line. Aristarchus measured the angle subtended and deduced from it the ratio of the distance very much too small. The same may be said of the plan employed by Hipparchus,and after him Ptolemy, which consisted in measuring the distance of the diameter of the earth's shadow in eclipse of the moon. The parallax of the sun at this time was set down at 3′, which is much too great. Kepler, Riccioli, Hevelius, and Vendelini, being provided with better means, reduced the parallax of the sun successively to 2′ 28″, and finally to 15″, the latter figure still being nearly twice as large as it should be.

By the three well-known astronomical laws of Kepler, which govern the motion of all the planets round the sun, and establish a connection between the duration of revolutions and mean distance, the sun's parallax was found to be by Cassini 10″, by La Hire 6″, by Maraldi 10″, by Pond and Bradley 9 to 12″, and by Lacaille 10·5″. The approximate parallax now known is 8·9″, which gives for the sun's distance 91,308,642 miles; until recently 95,000,000 miles has been adopted.

The earth's parallax taken from 8·578″ to 9·343″ gives a difference of 0·765″, and every tenth of a second is equal to 1,130,000 miles, so that this difference will bring the sun in the northern hemisphere about 3,000,000 miles nearer to the earth in winter, and in the southern hemisphere 3,000,000 nearer in the summer season.

Laplace arrived at a very striking result in this way from his researches on the value of the solar parallax; among the equations in longitude involving that element and varying with the angular distance between the sun and moon, the co-efficient of his equation, when compared with observation, was found to give 8·6″ for the mean value of solar parallax. The result agrees with the mean of those obtained, from the transit of Venus in 1769. "It is very remarkable," says Laplace, "that an astronomer without leaving his observatory, by merely comparing his observations with analysis, is enabled to determine the magnitude and figure of the earth and its distance from the sun and moon." (*Exposition du système du monde.*)

The protrusion of light from the sun indicates the presence of a medium of continuity; it is not wholly electrical because electrical action implies separation and reunion with force; it is therefore principally combustion of the metals of the alkalis and alkaline earths, which produce both light and heat with the greatest possible energy. It will appear clear, therefore, that a difference of the sun's distance from the earth, amounting to three millions of miles,would make a considerable meteorological difference to the earth and its atmosphere.

That the motions of the planetary system are derived from the solar motion is proved by the fact that their mean motions correspond with the plane of the solar equator,and the breadth of the planetary zodiac is taken at 7½ degrees on each side of the solar equator, while 7½ degrees is the inclination of its pole. The two large hemispheres above and below appear to be the articular region for the range of comets.

Professor Zollner's late investigation as to the origin of the earth's magnetism, and the magnetic relations of the heavenly bodies, draws the conclusion from simultaneous forces acting at a distance. He considers that the sun is a magnetic body like the earth. The earth in its annual course round the sun cuts a plane perpendicular to the ecliptic twice a year. On September 6th the south pole of the sun is towards the earth, and on March 7th the north pole, and whatever magnetic effects are produced on the earth by the sun will have their maximum at these two dates.

It is a well known law that every particle of matter in the universe attracts every other particle, with a force directly proportioned to the mass of the attracting particle, and inversely to the square of the distance between them. There is a disturbing force, oblique to the line joining the moon and the earth, which in some situations acts to accelerate, in others to retard her elliptic orbital motion—in some to draw the earth from the moon, in others, the moon from the earth.

The known mass of Venus is rather greater, and her density rather less than that of the earth, the force of gravity at her surface is about the same as on the surface of the earth, but she produces disturbing causes both in the orbit of the earth and the moon.

The mass of Jupiter being great, his influence is considerable in disturbing the other planets, the disturbance produced by him is the reciprocal effect produced in the motions of himself and Saturn. The mutual action of these immense bodies is of such a nature that if one be by the disturbance put before its mean place, the other will be behind its mean place. This inequality is of such a magnitude as at its maximum to advance or retard Saturn by 0·49′ in longitude, and to retard or advance Jupiter by 0·21′. This great inequality goes through all its changes of magnitude in about 918 years.

At a meeting of the R.A.S., Lieut. Col. Strange, F.R.S., in following the Astronomer Royal *as to the insufficiency of existing physical observatories*, or what is more recognised as physical astronomy, said if the study of the sun only was in question, that alone would justify such a measure. There can hardly be a doubt that almost every natural phenomenon connected with climate can be distinctly traced to the sun as the great dominant force. "It is my conviction," says Col. Strange, "that of all the fields now open for scientific cultivation, there is not one which promises results of such high utilitarian value as the exhaustive systematic study of the sun."

No one who has studied the combined sciences of astronomy and meteorology will deny that Col. Strange's suggestion is a step in the right direction.

The connection of planetary configurations and solar spots, with terrestrial magnetism and auroral phenomena, must tend to establish a connection between sun-spots and solar radiation. So long ago as August 1612, Galileo wrote, in the second of his three celebrated letters, that it was his opinion solar spots have some relation to the planets.

This principle has been made all but clear from a paper read by Mr. Meldrum at the meeting of the British Association, showing that cyclones of the Indian Ocean have a periodicity corresponding with sun-spots. Mr. A. Elvins, at Toronto, has fo many years recorded such astronomical phenomena and storm periods, the result of which, from his registered tables, is that storm periods usually occur at sun-spot maxima.

We may gather from these remarks that every solar disturbance receives an immediate response from the earth, and that the magnetic impulse travels sensibly with the velocity of light. There is a counterpart of such cyclones and lateral movements in the body of the sun, by which the wave-lengths of luminous vibrations of light are measured in passing from one colour of the spectrum to another, and by which means not only the rate at which solar storms travel over the sun, but which supplies a means for measuring the velocity of the stars, from which Dr. Huggins finds the motion of recession of from 15 to 28 miles per second, and the motion of approach amounting to 55 miles per second in the case of Arcturus. In early scientific history, we hear nothing notable of meteorology or its connection with any astronomical influences, either from the Egyptians, Chaldeans, or Phœnicians. In the 4th century before Christ, Aristotle relates to meteorology as being confined to the region intermediate between the earth and the region of the stars; the subject itself including enquiries into the nature of meteors, comets, and the Milky Way. The Egyptian priests are related to have kept registers, in which they entered notices of remarkable natural phenomena, such as the rain-fall in Upper Egypt, which they considered to be the cause of the inundation of the Nile. From the Chinese, who had fixed observatories, early records were obtained, some of which were employed by Laplace to determine the ecliptic obliquity, but they convey no knowledge of physical astronomy, such as solar spots, magnetism with its momentary changes, electricity, aurora or zodiacal light, or any united phenomena which emanate from the action of the sun. A very striking example of the transformation of force from the sun is given in planetary movements with very eccentric orbits. A cometary orbit, whose greatest elongation should extend beyond the distance of Neptune, while its perihelion should be within the orbit of Mercury, would acquire a velocity of from one to two hundred miles per second at perihelion, but at its remote aphelion its velocity would be reduced to two or three miles per second. Perhaps the best illustration on record of combined force from planetary conjunctions, in which the earth was connected, is recorded as having taken place November 27th, 1703, when five of the planets were in conjunction with the sun, Jupiter, the earth and moon, Venus, the sun, Mercury and Mars, at which time the most frightful storm ever remembered swept over the continent of Europe. There were blown down 800 houses, 400 wind-mills, 25,000 timber trees, 100 churches unroofed, 300 sail of shipping lost, 900 small crafts, 1,500 sheep. The loss in London was over a million sterling. Sir Cloudesley Shovel, with his fleet in the Downs, lost three ships of 70-guns, one of 64, two of 56, and one of 46, besides 1,500 men, who perished on the Goodwin Sands. It was on that day the whole structure of the first Eddystone Lighthouse, together with its architect, Winstanley, and other inmates, was blown into the ocean.

Knowing, therefore, that these astronomical connections, conjunctions, and appositions, together with other forces of a lesser character, produce such remarkable phenomena may we not hope that a better knowledge of the solar and planetary influences will enable us to make some approach to meteorological forecasts.

By knowing the true distance of the sun from the earth, and the greatest elongation of the planet, it becomes a simple question in plane trigonometry to ascertain the distance and size of all the planets in the system, a problem, the solution of which will for ever form an epoch in the history of mankind. The complicated movements of our globe, and the system to which it belongs, have been demonstrated in a general proposition by Lagrange and Laplace, viz., an invariable relation exists among the eccentricities of any number of perturbed orbits, and that the sum of the squares of the eccentricities, each multiplied by an invariable co-efficient, is itself invariable, and subject to no change by the mutual action of the parts of the system. The masses of the planets, and the constants of their motion, might all be changed from what they are (within certain limits) yet the same tendency to self-destruction in the deviations of the system (from a certain state) would still exist, so that at the end of each period of the system, all its parts are re-established in their original position to set out afresh, to run the same unvarying round for ever.

To James Gregory, a Scotch mathematician, is due the original suggestion of using the inferior planets for getting the parallax of the sun, although Halley has the credit of having first recommended to the notice of future astronomers an affecting exhortation not to suffer so precious an occasion as the transit of Venus in 1631 to pass unprofitably, but to deduce from this observation one of the most important elements of our system. Halley at this time was aware of the rarity of the transit of Venus, as the plane which Venus describes does not coincide with the plane of the earth's orbit owing to which circumstance two transits usually, but not always, occur in an interval of eight years, after which they do not again occur for more than a century, and always in June and December. If however a transit does not happen at the same node after an interval of eight years, it cannot take place again at that node for 235 years, which will be in the year 2117.

Venus, seen from the earth, accomplishes an entire oscillation round the sun in 584 days, and then returns to inferior conjunction again, but during this time the earth has made one entire revolution round the sun, besides having described an arc of about 216deg., five times which makes 1,080deg., or three circumferences of 360 deg., therefore at the end of five conjunctions, or five times 584 days, which is equivalent to 2,920 days, or eight years, the conjunctions are reproduced almost on the same day and in the same part of the heavens. The latitude of Venus and the sun however are not rigorously identical at the end of eight years, but present a difference of 20′ to 24′, therefore making a difference in 16 years of from 40′ to 48′, a quantity which surpasses the semi-diameter of the sun; these intervals therefore do not return again for more than a century, when they succeed each other as before.

In the year 1627 Kepler completed the Rudolphine tables which enabled him better to calculate the motions of the planets. In 1639 the planet Venus passed over the sun's disc, and on this occasion the transit took place unknown to any notable astronomer. It was only seen by two young amateurs, Jeremiah Horrocks, of Toxteth Park, near Liverpool, and William Crabtree, of Broughton, near Manchester. In taking the mean between the Rudolphine tables and those of Lansburg, Horrocks arrived at the position and time of both ingress and egress of the planet's transit over the sun's disc at 3h. 15m. p.m., on observing which it seemed to him at the moment as if Divine Providence had encouraged his aspirations in this most gratifying spectacle, the object of so many earnest wishes. This was the first recorded time the planet Venus was seen crossing the sun's disc. At this time Horrocks was but twenty years old, and he died three years afterwards. His companion, Crabtree, lived but a short time after him, when the world lost two young men of extraordinary promise, who have left an interesting account of this transit entitled "*Venus in Sole Visa.*"

The earth passes her ascending node in the beginning of December, and her descending node in the beginning of June. If to the date of the first transit seen by Horrocks and Crabtree, December 4th, 1639, we add 235 years, it will give the time of the forthcoming transit in December, 1874, at the same node. From her inferior to her superior conjunction, Venus appears on the west side of the sun, when she is a morning star. From her superior to her inferior conjunction she appears on the east side of the sun, and is then an evening star, alternating morning and evening star for a period of 292 days. Each time Venus never departs quite 48° from the sun; she is never seen at midnight, nor in opposition, being visible about three hours before sunrise, and about the same time after sunset.

The physical emanations in the sun are known to undergo remarkable changes, these emanations are to be found in the aurora, the zodiacal light, meteorides, etc.; the chemical emanation by which photographic impressions are produced, observed with the refracting telescope, requires a peculiar form of lens. The heat ray of lower intensity is conveyed to a focus by a lens of rock salt, as rock salt absorbs little or no heat, either dark or luminous, the calorific powers of the different coloured rays can be best compared by using a prism of this substance. The phosphorogenic ray for the refracting telescope is best transmitted by a lens of quartz, they are all however concentrated into foci by metallic reflectors.

The forthcoming transit will be recorded by photography, for which purpose preparations are being made in England, America, France, Prussia, Russia, Portugal, and many other places. By this means the epoch of each photographic record may be determined with accuracy, the time of the exposure being from 1-50 to 1-100 of a second. The angle of position of successive situations of the planet on the sun's disc, as shown on the series of photographs, and the distances of the centres of the planet and the sun, are data that determine the chord, along which the transit has been observed to within 0·1″, and an error of 1″ in the measurement will give an error of only 0·185″ in deduced solar parallax.

In the photographic method there is the possibility of a systematic distortion, either optical or mechanical, and where the determination of a definite point is so refined as that which will have to be of the solar parallax, any distortion may be considered a serious defect. The observation is also uncertain on account of irradiation, and being only momentary, if missed, the record is irretrievably lost.

The Americans propose to exclude the distortion error by dispensing with the secondary magnifier, and employing a lens of considerable focal length (40 feet) in order to obtain an image 1in. in diameter. This plan is also being adopted in Lord Lindsay's preparations, in order to obtain an accurate image of the sun at least 4in. in diameter formed by rays as little oblique as possible being reflected into the telescope horizontally by means of a heliostat.

Some observers intend using the spectroscope, especially for examining the dark ligament seen by some observers during last transit of Venus. This, however, is not always the case when first the opaque globe of Venus begins to touch the bright limb of the sun. "I know," says Captain Smyth, "by my own experience, it may be noted within a second of time." The same remark is made by Sir David Brewster, in his edition of Ferguson's astronomy, the times by observation of internal contact can be observed with much greater accuracy than any angular distance can be measured, and on this depends the superiority of the method.

Venus at that time is at her maximum size, being 61·236″, her mean value according to M. Arago, being 16·904″. When the elongation of Venus is 30° 44′ between its inferior conjunction and greatest elongation, it appears the brightest, and in this situation, Venus is often seen with the unassisted eye in broad daylight. At inferior conjunction the sun and Venus approach each other at the rate of 4 secs, in the minute, so that if the time of contact be erroneous at each place of observation 4 secs. of time, the angle may be erroneous, equal to 8-15 of a second; therefore the limit of error is about 4-15 of a second, so that an angle only 4-15 of a second can be measured, a less quantity than can be determined with certainty by any other method.

In conclusion: Suppose the two observers to be exactly 90° apart, a circumstance scarcely to be expected, yet by knowing the distance, and the greater the distance that the observers are apart on the Earth's surface, the more correct is likely to be the observation it will not be difficult to find the magnitude of the chord-line within the Earth, and from hence deduce what must have been the result had their distance been exactly 90°.

From previous observations the parallax of the sun is included within the limits of 8·5″, and 8·7.″; the mean 8·6″ has been adopted by Delambra, and Laland, but is not considered sufficiently correct. When the true distance of the sun has been determined, and all the planets in the system adjusted thereto, we may look forward with hope to the time when the conservation of forces which unite the planetary to solar influences may be brought to our knowledge, and give a principle of abstraction which will enable observors to obtain a correct investigation of those physical laws which control the earth and its atmosphere.