Determination of the Sun's Distance from Observations of Eros
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the other. In 1869 Williamson was able to point to similar structural modifications in *Dadoxylon*, and to show that regularly transitional forms gave proof of the derivation of the bordered pits from scalariform structure. Recent studies of North American Cordaitæ have given conspicuous examples of the same kind, and show that a continuous series of radial sections will display regularly transitional forms—often combined in the same tracheid—passing from the spiral vessels of the protoxylem through scalariform vessels, thence into tracheids with transversely elongated bordered pits, which successively become shortened up until there is developed the typical, multiseriate, hexagonal and compactly crowded bordered pit so well defined not only in the Cordaitæ, but also in the modern Araucarieæ. These facts possess the deepest significance from a phylogenetic point of view, since they afford an additional and reliable indication of derivation, and in the present connection, they serve to point with considerable force to the idea that among modern Conifera, the widely-separated bordered pit which in many instances wholly disappears is for that line of descent the culminating form of this type of structure; while in the Angiosperms the modification has been carried to a greater extreme and involves the reduction of the pit to the form of a simple slit or pore, and ultimately to its complete obliteration as a final expression of the secondary growth of the cell wall. Structural alterations of this nature involve also a more or less profound influence upon functional activity as expressed in the distribution of nutrient material.

I have thus endeavored, within the limits of the time at my disposal, to briefly indicate some of the more prominent directions in which paleobotanical activities have developed in North America within the last decade. While this review shows that some substantial progress has been made, that much has been accomplished in the direction of laying the foundation for future studies, and that the study of fossil plants is gaining greater prominence as a necessary aid to our knowledge of plant descent, it also brings into relief the fact that progress in this latter direction must of necessity be slow, and the result of laborious methods of investigation extending over such long periods of time as will permit the accumulation of great stores of material, and the careful piecing together of fragments which separately have little or no significance. Nevertheless the rapid progress which has marked our knowledge of fossil plants during the last twenty years, and the acceleration of this progress within the last two decades, together with a greater appreciation of the fundamental importance of such studies in questions of relationship, afford much ground for regarding the future of paleobotany on this side of the Atlantic as one of promise.

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DETERMINATION OF THE SUN'S DISTANCE FROM OBSERVATIONS OF EROS.

THE tendency of the time toward thorough organization and cooperation in large enterprises is well illustrated in modern astronomy. Twenty-five years ago, a dozen leading observatories, by mutual agreement, divided the northern sky into zones in such a way that their meridian circle observations would combine to form the excellent Astronomische Gesellschaft star catalogues; and this great work is now nearing completion. The work of charting the sky by means of photography was similarly organized by the Astrographic Conference in Paris some ten years ago.

About fifty of the principal observatories of the world are now cooperating in a great program of observation for improving our knowledge of the distance between the earth and sun. Fully half the resources of the Lick Observatory, the Lick Astronomical Department of the University of California, have been devoted to this work for three months past, and the observations will continue another month.

The determination of the value of this astronomical unit of distance is one of the most famous problems in the science, and a great variety of methods has been used. Perhaps the best determination is that made by Sir David Gill, of the Cape of Good Hope, from heliometer observations of the nearer asteroids. The four hundred small planets —asteroids—discovered up to 1898 all move in orbits situated entirely outside the orbit of Mars. The observations of Victoria, Iris and Sappho, which approach nearer to the earth than any of the other members of the asteroid group, led to the conclusion that the average distance from the earth to the sun is about 92,900,000 miles. The unavoidable errors to which all such observations are subject leave an uncertainty of some 150,000 miles in this value: it may be too large or too small by this amount.

The accuracy of results obtained in this manner depends upon the distance of the observed body from the earth and upon its definiteness as a point of observation. Mars possesses the advantage of being nearer the earth than the asteroids, but this advantage is greatly outweighed by the fact that an asteroid-point can be observed much more accurately than a large planet-disk. Gill's splendid work left much to be desired, but there was no prospect that his value of the unit could be improved with instruments now available.

An asteroid discovered by Dr. Witt in Berlin in 1898, to which he gave the name Eros, is very remarkable in that its orbit lies partly within and partly without the orbit of Mars. It approaches the earth more closely than any other member of our system, except the moon. The forms and relative positions of the orbits of the earth, Eros and Mars are shown approximately by the accompanying diagram, Fig. 1. The

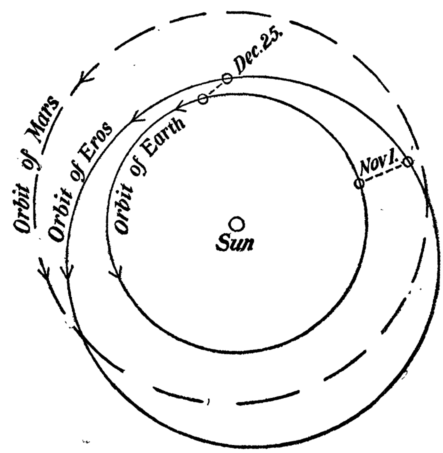

FIG. 1.

orbits of Mars and Eros appear to intersect, but this is merely apparent, from the projections of the two on the plane of the paper. The plane of the orbit of Eros makes an angle of about eleven degrees with the plane of the orbit of Mars (and the earth), and the two orbits are situated like two adjacent links of a chain, without approaching each other very closely.

As soon as the orbit of this wonderfully located asteroid was computed and published, astronomers realized its possibilities for improving our knowledge of the sun's distance. As stated above, an asteroid's value for this purpose depends upon its closeness to the earth. The distance of Eros at this opposition will have a minimum value of twenty-seven million miles. Unfortunately, the more favorable opposition of 1896, when the distance diminished to fifteen million miles, was not available, as the planet remained undiscovered; and an equally good opposition will not occur again for a quarter of a century.

In outline, this method of measuring the sun's distance is exceedingly simple; but in detail, it is exceedingly complex and technical. The nature of the problem may be explained from Fig. 2.

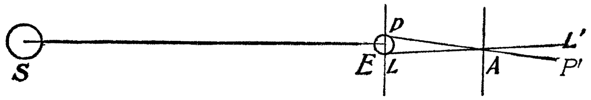

FIG. 2.

If the earth is at E and the asteroid at A, an observer on the earth's surface at P will see the asteroid projected on the sky at P', whereas an observer at L will see it at L'. If the distance PL is known, as it is, and the angle PAL is obtained from the observations, the data for solving the triangle PLA are at hand, and the distance EA may be obtained by simple computation. As a second step in the solution, the orbit of Eros will be determined very accurately, basing the determination upon Newton's law of gravitation. It will then be a simple matter to compute the ratio of the earth's distances from the sun (ES) and the asteroid (EA). The distance EA having already been determined in miles, the desired distance ES will follow.

If two observatories on opposite sides of the earth secure observations simultaneously, say at P (Pukowa in Russia) and at L (Mt. Hamilton), the desired data are theoretically complete; but practically they are insufficient. There are unavoidable errors in the measurement of the very small angle PAL, and in the assumed positions of the two observatories, which will be materially reduced by having observations made at a large number of stations. The direct distance between the Pulkowa and Lick Observatories is about 5,000 miles. This is a base line from which to measure a distance of 27,000,000 miles, and thence the three-and-one-half-fold greater distance to the sun. The form and the dimensions of the earth thus enter directly into the problem. An error of a quarter of a mile in the assumed length of the base line leads to a large error in the final result.

Instead of simultaneous observations made in the morning in Russia and in the evening in America, the angle PAL can be determined by evening and morning measures secured at one station.

The July conference of astronomers at the Paris Exposition afforded an opportunity for a hurried formation of cooperative plans to secure the observations needed. It may be said that every one of the contributing observatories is devoting to this problem all its resources which in any way promise to improve the results. The measures are most advantageously made in November and December; and perhaps a hundred observers are giving their time to this work. The reductions will require one or two years' labor, and the value of the sun's distance, resulting from a combination of all the work of all the observatories, will probably not be available for two or three years.

The Lick Observatory is contributing as follows:

Astronomer R. H. Tucker, assisted by Mr. Crawford, is securing two meridian-circle observations of each of 700 stars, to determine their positions with the utmost accuracy. These positions, furnished by perhaps a dozen or more observers, will form the triangulation system, or groundwork, upon which the whole structure of the determination will be based.

Astronomer W. J. Hussey and assistant-astronomer R. G. Aitken, with the assistance of Mr. Wright and Dr. Reese, are using the great 36-inch telescope five or six nights per week, weather permitting, to measure the evening and morning positions of Eros with reference to the fixed stars in the asteroid's vicinity. The positions of these reference stars will be secured by means of photographs of the regions taken with eight or ten telescopes, mostly in Europe.

Assistant-astronomer C. D. Perrine, assisted by Mr. Palmer, is employing the Crossley Reflector every clear night to obtain photographs of Eros and its surrounding stars, to furnish the planet's accurate position in the evening, in the morning, and on the meridian. The measurement of these plates will be a heavy task. Fortunately, Professor Rees, Director of the Columbia University Observatory, has volunteered to measure them. Columbia University is the only institution in this country which has had experience in measuring such plates, though many foreign observatories have long been doing similar work.

The planet Eros is now of about the 9.3 magnitude. It is easily visible in a three-inch telescope.

W. W. CAMPBELL,
Director of the Lick Observatory.

ON THE NATURE OF THE SOLAR CORONA, WITH SOME SUGGESTIONS FOR WORK AT THE NEXT TOTAL ECLIPSE.

IN an article on the corona, published in the November number of the *Astrophysical Journal*, I suggested a method by which the existence of the Fraunhofer lines in the spectrum of the corona might be detected. The method was based on the supposition that the light emitted by the particles in virtue of their incandescence, so overpowers the reflected sunlight that the lines are invisible. That the coronal light is strongly polarized is well known, and there is scarcely any doubt but that the polarized light is reflected sunlight. If now a Nicol prism be placed before the slit of the spectroscope in such a position as to transmit the polarized radiations, these will be allowed to pass with almost undiminished intensity, while the emitted or unpolarized light will be reduced in intensity by one-half. The great change in the ratio resulting might easily be sufficient to bring out the dark lines distinctly. I feel firmly convinced that this experiment should be tried at the Sumatra eclipse of next May, for I have successfully accomplished it in the laboratory with an artificial corona. It was found that a gas flame in a strong beam of sunlight shone with a pure bluish-white light, due to the reflection or rather scattering of the sunlight by the minute carbon particles.* The flame thus illuminated showed the Fraunhofer lines distinctly, but by reducing the intensity of the sunlight a point was reached at which they disappeared, and the spectrum appeared continuous. The light scattered by the flame was found to be *completely* plane-polarized in certain directions, giving us just the required conditions, namely particles emitting a continuous spectrum, and scattering a polarized solar spectrum. In front of the slit of the spectroscope a Nicol was arranged in such a manner that it could be drawn into and out of position by a cord. The Fraunhofer lines could be made to appear by sliding the Nicol in front of the slit, and disappear by drawing it away. While it does not by any means follow that the use of a Nicol on the actual corona will bring out the lines, the experiment seems to be well worth trying, as it would furnish further information regarding the relative intensity of the emitted and reflected light. Another interesting point is that the minute particles in the flame do not scatter the longer waves, the flame reflecting practically no red or orange light. Thus the Fraunhofer lines can only be traced up to about the D lines. By gradually reducing the intensity of the sunlight they disappear first in the yellow, then in the green, blue, and violet in succession.

* A photograph of the flame with a spot illuminated by powerful convergent beams of sunlight furnishes a beautiful proof of the existence of solid particles in the flame.