NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXV—THIRD MEMOIR

BIOGRAPHICAL MEMOIR

OF

WILLIAM WALLACE CAMPBELL

1862–1938

BY

W. H. WRIGHT

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1947

W. W. Campbell

WILLIAM WALLACE CAMPBELL

1862–1938

BY W. H. WRIGHT

William Wallace Campbell was born on a farm in Hancock County, Ohio, on April 11, 1862. He was the son of Robert Wilson and Harriet Welsh Campbell. The Campbell family, of which Wallace was the youngest except for a son who died in infancy, consisted of three sons and three daughters, none of whom survived him.

Robert Campbell was of Scotch descent. In 1745 or 1746, a time of great unrest in Scotland, some Campbells emigrated from there to County Down, Ireland. In 1785 seven brothers of one Campbell family sailed for America, and settled in Western Pennsylvania, probably Washington County. In 1838 James Campbell and his wife (Jane Wilson) moved from Pennsylvania to Hancock County, Ohio. Their third child, Robert Wilson, married Harriet Welsh, also from Western Pennsylvania. Harriet had come with her family to Ohio in 1837, when she was a child of about eleven, and it is related that she walked most of the way. Robert Wilson Campbell and Harriet Welsh had seven children, of whom, as already has been said, William Wallace, or as he came to be called, Wallace, was the sixth.

Robert Campbell died in 1866, and Wallace had no recollection whatever of his father. The mother had six children to rear, and did it successfully at the cost of very hard work. She appears to have been a person of exceptional intelligence, though she had little opportunity to acquire a formal education. She is reported to have "done arithmetic in her head", that is to say, without recourse to pencil and paper, a circumstance which seems worth noting because her son had the faculty of carrying on calculations with a minimum recording of figures. He not uncommonly looked up two or more logarithms, added them mentally, took out and set down the product—a feat which always excited wonder on the part of one who has no talent whatever for arithmetical computation. Campbell's earlier scientific work was in computational astronomy, and it is hardly to be doubted that his ease with numbers had much to do with his success in that field.

Robert Campbell was an expert carpenter and cabinet maker, the quality of his workmanship being attested by furniture of his construction still in the possession of his son's family. While in his mental traits Wallace appears, in the opinions of those who knew him as a boy, to have favored his mother, there seems to be little room for doubt that he inherited substantially from both of his pioneer parents.

As a child Wallace had to work very hard. "When he was quite little he had to do chores on the farm, and help hoe the vegetable garden." In later years his wife voiced the suspicion that this may have been the cause of his total lack of interest in gardening: "He loved flowers if someone else would raise them." Be that as it may, one can but assume that Campbell's early experience on the farm had much to do with the formation of that habit of industry which was so conspicuous a trait of his developed character.

Wallace attended the local schools and was much indebted to one of his high-school teachers, a Miss Abbot, for sympathy and encouragement. She recognized his ability and urged him to attend a university of recognized standing, rather than one of the small colleges which are so plentiful in Ohio. After a year or two of school teaching he was able to act on this advice, and in 1882 he applied for admission to the University of Michigan as a student in civil engineering. Here he encountered difficulties deriving from the low standards of the schools he had attended, but the committee of the faculty having to do with such matters decided to give the boy a chance, and the University can hardly have had occasion to regret their action in admitting him.

Campbell was graduated by the University of Michigan in 1886, with the degree of Bachelor of Science, but it is here necessary to step back a little to record an incident of his undergraduate experience which decisively affected the course of his life. One day, during his third college year, while reading in the University library, he happened upon a copy of Simon Newcomb's *Popular Astronomy*. His interest was so captured by the opening paragraphs of the book that he read it through in two days and two nights. In later years he was accustomed to tell his friends that then and there he "discovered" astronomy and decided to make it his life's study. Under the guidance of Professor J. M. Schaeberle, who was in charge of the University observatory, he became a skillful observer, and after devoting a vacation period to the reading of Watson's *Theoretical Astronomy*, he undertook with success the calculation of comet orbits. During his last year at the University he served as an assistant in the observatory. For two years after graduation, Campbell was Professor of Mathematics in the University of Colorado. While there he met Elizabeth Ballard Thompson, a student at the University, to whom he was afterward married.

In 1888 Professor Schaeberle resigned his position at Ann Arbor in order to join the staff of the Lick Observatory, which opened for operation in the summer of that year. A vacancy was thus created in the department of astronomy at Michigan, and the University invited Campbell to come as instructor. This offer provided an opportunity for him to enter his chosen field, and at a very considerable financial sacrifice he accepted it. During the summer vacation of 1890 Campbell served as voluntary assistant at the Lick Observatory, and helped Astronomer James E. Keeler in his spectroscopic observations. Shortly thereafter Keeler left Mount Hamilton to accept the directorship of the Allegheny Observatory, and two young astronomers, Wallace Campbell and Henry Crew, were invited to come to the Lick Observatory to engage in spectroscopic work. Crew left after a year's service, to become Professor of Physics at Northwestern University, while Campbell remained in charge of the spectroscopic work of the Lick Observatory.

Campbell received his appointment on May 12, 1891. Inasmuch as he was then entering upon the work for which he subsequently became distinguished, it seems appropriate to sketch briefly the state of astronomical spectroscopy at that time. The capital discovery by Kirchoff and Bunsen of the law of spectral absorption that bears the former's name, which law provides the basis of spectroscopic analysis, had been made only 31 years before. In the interim much valuable work, which, viewed through the frame of present knowledge may be described as largely of a qualitative character, had been accomplished, both in the spectroscopic analysis of the heavenly bodies and in the measurement of their velocities through the employment of the Doppler-Fizeau principle. It so happens, however, that the measurement of a photographic plate for either of the mentioned purposes must be accomplished with extraordinary accuracy, and, with the use of the stellar spectrographs of that day, the error of measurement was in the majority of cases of the order of the quantity sought. These comments are not to be regarded as generally applicable to spectroscopic procedures of the era of which we are speaking, but as relating particularly to astronomical spectroscopy where, because of the faintness of starlight, and of other circumstances of astronomical observation, a less degree of precision had been obtained than in general laboratory practice. Faintness of a stellar spectrum usually necessitates a long photographic exposure, while the spectrograph, being attached to a moving telescope, is subject to disturbance by differential flexure at various stages of the exposure; furthermore, the effects of changing temperature must be guarded against. Generally speaking, the instruments available fifty and more years ago served in measuring relatively large radial velocities, but were useful only in a limited way in the study of the velocities of the great majority of stars.

An exception to the above restrictive comment should perhaps be made in the case of some visual observations made in 1890-91 by Keeler, of the velocities of the more conspicuous nebulae whose spectra consist predominantly of emission lines. Keeler took advantage of the fact that the bright lines are not weakened by the employment of high dispersion, and was thus, in respect to this particular group of objects, able to make observations which conform to present standards of accuracy, but his procedures were not applicable to the study of the vastly more numerous stars. He had in mind the construction of a spectrograph to undertake the larger work, but was unable to realize his desire until after he moved to the Allegheny Observatory.

It was in this investigation that Campbell had assisted Keeler during the period of his voluntary service at the Lick Observatory in the summer of 1890. Campbell's early association with Keeler cannot be regarded as other than fortunate both for himself and for the Lick Observatory.

It is convenient for the purpose of this biographical summary to divide Campbell's active association with the University of California into three periods. These are: first, the initial period of approximately ten years, 1891 to 1901, during which he held the position of astronomer in the Lick Observatory; second, the interval 1901 to 1923, during which he was director of the Observatory; and third, 1923 to 1930, when he filled the offices of president of the University and director of the Observatory. There followed a fourth period, that of his retirement; this included his service as president of the National Academy of Sciences.

During the first of these intervals he was extraordinarily active as an observer, and did the greater part of his observational work. He had hardly settled himself in his new position at Mount Hamilton when a brilliant "new" star flashed in the heavens: Nova Aurigae of 1892. This was by far the brightest nova that had appeared since the employment of the spectroscope in astronomical observation, and little was known of the nature of a nova spectrum. A new field was opened to the young astronomer, and he entered it boldly with everything he had, which, however, was not a great deal, judged by modern fashions in spectroscopic equipment. It is true that he had the use of a powerful telescope, but his spectroscope, the one used by Keeler in observing the nebulae, was not an instrument suited to rapid observation or to faint objects. The spectrum of a nova changes from hour to hour, and sometimes alters its character altogether from night to night, so that speed is essential to successful observation. Moreover, the spectroscope was designed for visual use, while most spectroscopic observations, even at that time, were made photographically. Nevertheless, Campbell made most creditable observations of the star and, by dint of observing it as early as practicable in the morning sky when it again came into observation, he showed that its spectrum had lost its continuous character, and resembled that of a gaseous nebula. Equally important were the observations made by him at about that time of the spectra of nebulae and of Wolf-Rayet stars. Some of Campbell's findings were so surprising as to excite incredulity, and to bring upon him from certain quarters sarcastic and bitter criticism. To mention an instance: he reported a variation within the Orion nebula of the relative intensity of the F line of hydrogen on the one hand, and the bright nebular lines, then known as N_1 and N_2, on the other. Variations in the relative intensity of various lines within the body of a single nebula are now well known, and provide the basis for determining some of the physical conditions within the nebulae, but Campbell's observation was the first of its kind, and was, for a time, lightly treated by a highly placed critic. (97) (103) (113) (114); *cf Astroph. Jour.*, **10**, 164, 167.

In those early days Campbell had a number of controversies with astronomers who were disposed to question his findings, especially when these did not conform to currently accepted views. He was a very careful observer, and when he was ready to describe an observation he was confident of its validity. On the other hand he was young, his name was a new one in astrophysical literature, and this may have served to divest his critics of due and reasonable caution. Eventually they seemed to become more circumspect. Perhaps his most stubbornly defended conclusion was that water-vapor and oxygen are relatively scarce in the atmosphere of the planet Mars. His first observations were made at the favorable opposition of the planet in the summer of 1894. At that time Mars, and the possibility of its being inhabited by intelligent beings, occupied a large part of the public's interest in astronomy, and even conservative astronomers had been won to the view that the planet had an atmosphere, with water vapor and oxygen as constituents, that is to say an atmosphere which inferentially is capable of supporting life. In Young's *General Astronomy* (Edition of 1891), the text book most commonly used in American colleges of the day, occurs the statement, in relation to the atmosphere of Mars:

"Dr. Huggins has found with the spectroscope unequivocal evidence of the presence of aqueous vapor." This may fairly be taken as the accepted view of that period. For reasons that need not be given here, the spectroscopic detection in the atmosphere of a planet of a vapor, such as oxygen or water-vapor, that is also present in the earth's atmosphere, is one of the most difficult tasks in the astronomical spectroscopy. Campbell was alive to the difficulties and exercised the most painstaking care to minimize them. His conclusion, based upon his own observations, was that if water vapor or oxygen occur in the atmosphere of Mars it is in quantities too small to have been detected by spectroscopes then available. This conclusion ran so counter to the view generally accepted at the time that it was sharply criticized by some astronomers, more especially by those who were disposed to interpret the phenomena observed telescopically on the surface of Mars in terms of a rather tight analogy with what happens on the earth at this particular stage of our civilization and economic development. The controversy continued for some years, and even so late as 1909 observations were published which were interpreted by their sponsors as proving the very considerable occurrence both of water-vapor and oxygen in the atmosphere of Mars.[1] Campbell returned to the problem in 1909. In order to minimize the effect of the earth's atmosphere an elevated observing station seemed desirable, and he conducted an expedition to the summit of Mount Whitney, elevation 4420 meters, the highest point in the continental United States, to make his observations. The methods used on that occasion were similar to those that had theretofore generally been employed, but in 1910 he attempted to solve the problem in a different way, namely, by observations of Mars when near quadrature. In this position the planet has a considerable velocity, either of recession or approach, and any lines due to absorption in its atmosphere would be displaced from analogous lines imposed by the atmosphere of the earth, and thus be made apparent. This ingenious method had been conceived independently by V. M. Slipher, of the Lowell Observatory, and by Campbell. The

[1] *Lowell Obs. Bull.* Nos. 36 and 41.

observations were, in this instance, made at Mount Hamilton. The results of both the 1909 and the 1910 trials were negative, in conformity with those of earlier years, (210) (211) (222).

This evidence did not satisfy the contenders for the existence of life-supporting constituents in the atmosphere of Mars. Finally the inquiry was taken up by Adams and St. John at Mount Wilson. In 1925, after using the powerful permanent installations at the Mount Wilson Observatory, these observers came to the conclusion that the amount of water vapor was 3% of that over Pasadena on the day of observation, and the amount of oxygen was two thirds of that calculated to be above Mt. Everest.[2] These quantities are well within the tolerances indicated in Campbell's observations and would be incapable of supporting life as we know it on the earth. Thus was substantiated, in later years, Campbell's early finding that the amount of water-vapor in the atmosphere of Mars is relatively small. Aside from the purpose for which they were introduced, the incidents related illustrate the difficulty of removing a myth or misconception from scientific literature once it has become effectively lodged therein.

It was with such work as could be done with the limited spectroscopic equipment at his disposal that Campbell occupied himself during his early years at Mount Hamilton until he should have the use of a suitable spectrograph; in fact, as shown by his bibliography, he contributed at that time many papers on subjects outside the field of astronomical spectroscopy. His experience indicated to him the inadequacy of astronomical spectrographs of that day, and he set himself the task of improving them. Means for the construction of a new instrument were generously provided by Mr. D. O. Mills, a sympathetic friend of the Observatory, in the year 1893, and arrangements were made with the optical firm of John A. Brashear to build the spectrograph under general specifications to be provided by Campbell. The latter had the benefit of a very clear and comprehensive statement of optical principles of the spectroscope in a paper then recently published by Keeler,[3] and in the mechanical design of the in-

[2] *Astroph. Jour.*, **63**, 137, 1926.

[3] Elementary Principles Governing the Efficiency of Spectroscopes for Astronomical Purposes. *Sidereal Messenger*, 10, 433, 1891.

strument he adopted elements of construction originated both by Keeler and by himself. As is not unusual with instruments of precision, the spectrograph took a long time to build and to test, and it was not until the summer of 1896 that Campbell regarded it as satisfactory (99). Shortly thereafter, his attention was turned in another direction. An expedition to observe the eclipse of the sun of 1898, in India, was projected by Director Holden, and Campbell was entrusted with its organization and conduct. To free him for this duty an assistant was provided to carry on the spectroscopic observations during his absence on the expedition. In October, 1897, shortly before Campbell's departure for India, Director Holden resigned his position, and left the Lick Observatory. Keeler was appointed to succeed him as of July 1, 1898. Although Keeler had, in his earlier engagement at the Lick Observatory, been in charge of spectroscopic work, on assuming the directorship he delegated the responsibility for the 36-inch refractor and the new spectrograph to Campbell, who had just returned from India, and turned his own attention to the Crossley reflector, a relatively new acquisition by the Observatory, which no one else had succeeded in employing to advantage. Keeler overcame certain mechanical defects of the reflector mounting, and began a brilliant series of photographic observations of the nebulae which was most unfortunately terminated by his death on August 12, 1900. Campbell followed Keeler in charge of the Observatory, and was designated director as of January 1, 1901.

During the two years of Keeler's administration Campbell had been busily occupied with the new spectrograph and had made a number of interesting observations, the most outstanding of which was that of the complex nature of the motion of Polaris, which was at the time regarded as indicating that star to be triple, (116). This observation, together with the detection of a large number of spectroscopic binaries, and, generally speaking, the measurement of the radial velocities of stars with unprecedented accuracy, was made possible by the excellent performance of the Mills spectrograph. In fact this instrument, by permitting the attainment of new standards of precision, greatly enlarged a field of astronomical study which had until then been but crudely cultivated. It may be worthy of remark that essentially no new principle, either of optics or engineering design, went into the planning of the spectrograph—one just as good might well have been built in the earliest days of stellar spectroscopy and in all the intervening time been used toward the furtherance of astronomical knowledge. The principles of geometrical optics, which provide a basis for design of most stellar spectrographs, had long been familiar, and the making of stable mechanisms was no new thing.

In view of Campbell's accomplishments, it was but natural that he should be selected to follow Keeler as head of the Lick Observatory. His appointment as director brought to an end the first of the periods into which we have divided his professional life. In it, as has already been said, he did by far the greater part of his work as an observer. A glance at his bibliography will indicate something of his activity in those days; in fact, the bibliography is to be regarded as the corpus of this account, the purpose of the running text being merely to sketch briefly the circumstances which from time to time gave direction to his work. After assuming the administration of the Observatory, Campbell found it necessary to leave the observations very largely to others, though he occasionally took a hand in them. An exception is to be noted in respect to the observation of solar eclipses. He was much interested in these phenomena, and when one was to be observed he was active in every phase of the scientific preparations, and in the conduct of the expedition. This subject will be returned to later.

Campbell's original radial velocity project, regarded in the light of its later development, was modest. As I was at that time his assistant, he naturally spoke to me of his purposes. The more important of these was to issue a catalogue of radial velocities; the second was to calculate, on the basis of this catalogue, the sun's motion among the stars. The possibility that spectroscopic binaries in considerable number might be discovered during the course of the work (there were but a few known at that time) was suggested to him, but he seemed not much impressed. There were about 260 stars on the original program, chosen for their brightness and the measurable quality of the lines in their spectra. They were all north of —20° declination, and, with a few exceptions, were brighter than 5.5 magnitude. They were selected principally from classes F to M, as these spectra are rich in measurable lines. It was expected that each star would be observed four times and that, with luck with the weather, the observations would be completed in about four years. However, as the planned observations approached completion, it was found that those of certain stars on the list had to be repeated (this was especially true in the instances of such stars as had been found to have variable velocities) so that, to fill in the observing time, additional stars were inserted in the list. Finally, to make the work more comprehensive, a completely new list of stars extending in declination —30° was formed. This list contained 830 entries and was eventually succeeded by others too numerous to record, with the result that at this writing, fifty years after the inception of the program, the observations are continuing, and the end is not in sight.

Campbell had realized quite early in his undertaking that in order to complete the catalogue, and to stabilize the solution for the solar motion, it would be desirable to have observations of radial velocities of stars in the southern hemisphere of the sky, and the project of an expedition to obtain them was never very far from his mind. When he became director, he brought this need to the attention of Mr. Mills, and the latter most generously made financial provision for such an undertaking, (151). In 1903 an observatory, with a powerful reflecting telescope and suitable spectrograph, was established on Cerro San Cristóbal, a high hill in the suburbs of Santiago, Chile. The original plan was for an occupancy of about two years, but results secured were of sufficient importance to induce Mr. Mills to provide for the continuance of the work, which he did during the remainder of his life. After his death, in 1910, the project was sustained by his son, and by other friends of the Lick Observatory. Finally in 1929 the expedition was terminated, and the observatory, with its equipment, was sold to the Catholic University of Santiago, which it is understood still operates it. Campbell planned the observatory, but was never able to go to Chile to see it. It was installed and operated by members of the Lick Observatory staff assigned to those duties.

After the Chilean station got into production, grist came to the hopper from two sources, and the harvest was a rich one. The matter of making the product available to astronomers naturally occupied Campbell's mind. Items of particular interest, such as variable radial velocities, observations of novae, and the like, were promptly published and the quality of the work as well as its scope was indicated. Notwithstanding this liberal disposition, requests, which in instances fell little short of demands, were made that all the information be published promptly. The observatory was in effect accused of retaining data that belonged rightfully to the astronomical public, but there seemed to be no reason to stop in the course of an unfinished program of work in order to issue incomplete determinations of velocity which would eventually require revision. The desire of astronomers to know the radial velocities of as many stars as possible is easy to understand when one recalls that these quantities are fundamental in the calculation of the scale of the stellar system and of the "universe." Most other observations of the stars provide only angular movements, which of themselves supply no knowledge of the absolute (as distinguished from the relative) distances of the stars. The spectroscope, by giving the measure of a star's speed in the line of vision, enables a statistical evaluation of the speed at right angles to that line, which, combined with the observed angular motion, permits the calculation of the average distance of a group of stars. In special instances, for example in the cases of double stars and moving clusters, the distances of individual stars can be derived. Thus interest in the accumulating store of velocity determinations at Mt. Hamilton is readily understood, and Campbell did his best to meet reasonable requests for information. Special observations, or groups of observations were generally available to any responsible person who asked for them. If Campbell's attitude in this matter requires justification, it is to be found in the fact that radial velocities are subject to systematic errors of various kinds, and these errors can be evaluated only through comprehensive analysis of large groups of observations. One type of systematic error was found to run continuously through the whole series of observations, while another affected only observations made within a certain period of time. Then there is the so-called K-term, which Campbell had found in an early summary of his work, (230) (231) (239). This "term" represents systematic shifts in stellar spectra, dependent upon spectral class, equivalent to velocities, outward from the sun, as high as 4 km. per second. These and other effects had to be isolated and evaluated through a study of all the available material. Had the observations been released in advance of the determination of the corrections necessary to neutralize, or offset these effects, erroneous conclusions would almost certainly have been drawn from the data. The radial velocities of all stars measured at the Lick Observatory, up to January 1, 1927, 2771 in number, were published in catalogue form by Campbell and Moore in 1928, (325). The catalogue is accompanied by a comprehensive discussion of the observations, a redetermination of the elements of the solar motion, and provides a very complete history of the Lick Observatory radial-velocity project. It constitutes the most extensive and homogeneous body of information relative to the radial velocities of stars that has yet appeared.

An account of Campbell's work would be incomplete without some reference to its influence on that of others. Before he began his measurement of the radial velocity of stars such measurements were carried on with only indifferent success at two or three observatories. Following his initial success, a great interest developed in observations of that kind. Campbell's paper: "The Mills Spectrograph of the Lick Observatory," published in 1898, was widely read. His counsel on technical matters was frequently sought, and always freely accorded. Young astronomers trained at the Lick Observatory went elsewhere, and sometimes established themselves in this fertile field.

A very considerable number of the observatories of the world now devote to the measurement of stellar radial velocities a substantial part of their resources, and their combined output of data greatly exceeds that of the Lick Observatory. Probably none will deny to Campbell his due measure of credit for the stimulation of this great development.

When the radial velocity program was first undertaken at Mt. Hamilton, in 1896, about a dozen spectroscopic binaries were known. The orbital motions were, in all these instances, large, and the spectroscopic displacements through which the binary character was revealed were, due to this circumstance, relatively great and had easily been detected with instruments of relatively moderate power. It quite soon appeared from the Lick Observatory observations that stars of this class were more numerous than had been thought, and that the Mills spectrograph, through the attainment of a high degree of precision in measurement, had developed a special field for discovery and study. Further experience confirmed the conjecture that spectroscopic binaries are relatively numerous, and it has been shown that about one star in three has a periodic disturbance of its motion due, undoubtedly in most instances, to the influence of an unseen companion star. It is, however, appropriate to point out that modern research has shown that apparent periodic variable motion in a star can be caused otherwise than by a disturbing companion. In the case of stars that are Cepheid variables a disturbance is believed to be caused by "pulsations" in the star which carry the atmosphere back and forth, so that it is the star's atmosphere which moves, not the star's center of mass. This comment has a definite relation to the sensational discovery made by Campbell in 1900, and already briefly referred to above, that Polaris, the North Star, is multiple. Its velocity was shown to have a compound oscillation, a period of approximately four days being superimposed upon one of several years. (The longer period has since been shown by Moore to be 29.6 years.) It was therefore inferred that Polaris is a triple system, consisting of a bright star revolving about an invisible one once every four days, while this close pair revolves about a distant star in the course of years, and an announcement was made to that effect. However the discovery was subsequently made by Hertzsprung that Polaris is a Cepheid variable, and it is now believed that the four-day period is the consequence of pulsation in a single star. According to this view the system is a double one, with a period of revolution of 29.6 years.

While Campbell regarded the radial velocity observations and the problems relating to them as constituting his most important work, he was actively interested in other phases of astronomical spectroscopy, perhaps more especially in the spectroscopic study of solar eclipses, as has already been mentioned. One was never quite sure whether he enjoyed more the intense concentration during the critical moments of totality, or the excitement of preparation and travel incident to the undertaking, which sometimes occupied the larger part of a year. To one living on a relatively isolated mountain top, an opportunity to see the world under extraordinarily interesting circumstances is not a negligible matter, but it may be said of Campbell that, whichever of these two aspects of an eclipse expedition appealed to him the more, he served them both well.

Perhaps Campbell's most important eclipse observation was that in confirmation of the work of Eddington and his associates who, at the Brazilian eclipse of 1919, verified the gravitational deviation of light which had been predicted by Einstein from the general theory of relativity. Einstein's prediction of a deflection of star light by the sun's gravitational field, amounting at grazing incidence to 0.″83, based on what has come to be known as the Restricted Theory of Relativity, was made in 1911. Plans to test the prediction at the Russian eclipse of 1914 were made by Campbell and Curtis, but it was a "cloudy eclipse," and nothing came of the attempt. In 1915 Einstein developed the General Theory of Relativity, and from it predicted a deflection of 1.″75. The same observers tried again to detect the deflection, this time at the eclipse of 1918, at Goldendale, Washington, in the northwestern part of the United States. Their equipment was limited, inasmuch as the instruments used in the attempt of 1914 had been held in Russia as a consequence of the first world war; however, they improvised some cameras and obtained photographs of the star field surrounding the sun. It was hoped that, despite the optical shortcomings of the apparatus used in taking them, these photographs would suffice for the proposed test. The plates were measured and discussed by Curtis who came to the conclusion that they lent no support to the relativity prediction. In the following year, 1919, Eddington and his associates reported, in a communication to the Royal Astronomical Society,[4] that the relativity prediction had been verified by their observations of the Brazilian eclipse in the spring of that year. At the time of this announcement Curtis had left the Lick Observatory to accept the directorship at Allegheny, and Campbell, with the aid of Moore and Trumpler, undertook an examination of his discussion of the 1918 observations. As a result of that inquiry Campbell decided to attempt to measure the relativity deflection at the next favorable opportunity, which would occur at the eclipse of 1922. To this end preparations were made with extraordinary care. The site selected for the observing station was on the west coast of Australia, and there Campbell, with the assistance and collaboration of Trumpler, obtained photographs of a highly satisfactory quality. On the return of the party to California, Campbell was met at the steamer by a delegation from the regents of the University of California, who offered him the presidency of the University. His first disposition was to decline the offer; he was quite satisfied with the office he then held, and wished to continue in it. However he finally yielded to the persuasion of the regents, and accepted their offer, subject to conditions relating to the organization of the University, which were approved by them. On assuming the presidency of the University he retained, nominally, the directorship of the Observatory, without remuneration in that capacity, and Astronomer Robert G. Aitken was designated associate director, with enlarged functions of administration. Campbell was somewhat widely criticised for not relinquishing completely the directorship of the Observatory on becoming president of the University, but a

[4] *Mem.* R.A.S., **62**, Appendix, 1920.

careful consideration of the circumstances under which he assumed his new responsibilities will, it is thought, justify his action. The presidency of the University of California is a peculiarly exacting administrative office. Campbell was sixty years of age, with a successful career as a research astronomer behind him, but was without experience of the particular kind required in the management of a large teaching university. He might find the new task uncongenial, or unsuited to his tastes or abilities; and there are always the exigencies of university policy and politics to be considered in such a matter. Indeed the terms of most of the former presidents had been relatively short. That Campbell should undertake the proposed duty was not his own idea but that of the University regents, and there was in the circumstances no reason why, in setting foot to a new path on their solicitation, he should cut off access to the one he had followed with success for more than thirty years. In these circumstances the formal retention of the observatory post would appear to be natural.

With the appointment of Campbell as president, the task of measuring and reducing the plates taken at the 1922 eclipse devolved upon Trumpler. In two papers, authored jointly by Campbell and Trumpler, (315) (322), the results of the investigation are given. There are two sets of observations, made with separate batteries of cameras. The values of the deflection, reduced to the sun's limb, are in one instance 1.″72 and in the other 1.″75. They thus verify the value predicted by Einstein from the General Theory of Relativity; namely, a deflection of 1.″75.

As the record stands, two attempts have been made at the Lick Observatory to confirm the gravitational deflection of light, the first of them, in 1918, gave a so-called negative result; the second, made in 1922, which has just been described, provided a full and complete check of the theory. While there can hardly be a question of the validity of the second result, the situation has its awkward aspects, and it is to be hoped that eventually the earlier attempt at confirmation will be reviewed by a qualified person.

Campbell's administration of the University was most successful, as the following quotation from an appreciation of his life, prepared by a committee of the Academic Senate of the University, testifies:[5]

> "For six months before he entered upon his duties as President, he devoted himself to the University's history, organization, functions, and problems—all with his usual thoroughness. During this period he sought the advice of leading men of the factulty. As a result he entered upon his duties as President with a remarkable grasp of the University's functions and needs.
>
> "His devotion to truth and his belief in using the methods of science were evidenced in all his acts and policies. 'The fundamental purpose of universities,' he announced in his inaugural address, 'is to hasten the day when all men and all women shall have comprehension of the truth, so that they may live their lives more richly and more usefully in this exceedingly interesting world.' 'The first . . . obligation of a university,' he continued, 'is to instruct the students who come knocking at its doors; to disseminate . . . the knowledge that has been gained and preserved in all past time.' 'The second great function of a modern university is to extend the frontiers of knowledge into regions as yet unexplored.' Every professor, in his opinion, faced the duty of doing something to add to our store of human knowledge.
>
> "The Academic Senate closed an address to President Campbell concerning his retirement with this characterization: 'Your administration has been a period of tranquillity and healthy growth such as few universities have enjoyed, and we, the Academic Senate, desire to express to you our heartfelt appreciation.' Dr. Campbell gave himself wholeheartedly to the duties of the presidency, mindful of the good of the institution. His policies harmonized with the truth; his decisions seldom required revision. Of his conduct of the presidency, Regent Chester Rowell has said: 'With a hand always gentle but always firm and never shirking, President Campbell ruled the University wisely and well. Whether in its nominally ruling board, in its faculty, or in its student body, there are problems great and small in every university. The great ones, Dr. Campbell faced greatly, seeing them in the full perspective of the long

[5] *In Memorium*, 1938, The University of California, pp. 5-6.

future and of their wide ramifications, as was natural to a scientist whose habitual intellectual background had been the whole harmony of the universe.' "

Campbell was retired in 1930 from the presidency of the University and the directorship of the Observatory. In recognition of his long and excellent service the regents of the University invited him to continue indefinitely in the occupancy of the residence at Mount Hamilton that he had enjoyed for so many years, and he made more or less tentative plans for the resumption of scientific work. He was, however, in failing health, and had in the later days of his residence in Berkeley lost the sight of an eye. Furthermore he had been occupied almost exclusively with administrative matters during the preceding eight years, and in that time developments in astronomical spectroscopy, the field of his special interest, had been prodigious. I recall one day standing near him in the small mountain post-office where the members of the community customarily gather at noon to receive their mail, and word from the world. He opened a letter, read it once and again, then handed it to me with the question "What do you think I ought to do about this?" It was a note from the nominating committee of the National Academy of Sciences asking whether he would accept the nomination to the presidency of that body, which nomination is virtually equivalent to election. In view of the circumstances that have just been sketched, and not realizing the magnitude of the task to which he would set himself, I urged that he accept, which after some deliberation he did.

Campbell assumed the presidency of the National Academy on July 1, 1931. He was deeply sensible of the responsibilities imposed by the office, and, in order that he might be free to discharge them, he and Mrs. Campbell established a home in Washington, where they lived for the greater part of his term of office. Campbell devoted to his new position the same particular and minute attention that he was accustomed to accord to whatever he had to do, and the business affairs and general routine of the Academy were well ordered; but it will probably be agreed that the outstanding feature of his administration was the zeal with which he sought to uphold the prestige of the Academy, especially by strengthening its position as adviser on scientific matters to the Government of the United States.

It will be recalled that the Academy was created by the Congress in 1863, during the American Civil War, through an act of incorporation which specified no duties other than that the Academy should hold an annual meeting and should "whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art . . ." For many years following the establishment of the Academy the Government sought and received from it advice upon important matters, but in the decade or more preceding Campbell's term as president there developed, perhaps in part inadvertently, a tendency to delegate advisory functions to newly created bodies. It was Campbell's view that the act of incorporation, reinforced by the record of the Government's practice in seeking the Academy's advice, established the Academy as presumptively the advisory agency to the Government on scientific matters, and he sought by all means in his power to keep open the channel through which such advice might flow. "With tremendous courage and persistence, irrespective of personal considerations, he succeeded in obtaining fullest recognition of the Academy by the President (of the United States) through the creation within the Academy, on invitation of the President, of the Government Relations and Science Advisory Committee."[6] In the words of a qualified and eminently fair commentator upon Academy affairs of that period, whose views on method and procedure were not uniformly consonant to those of Campbell, "Campbell had a high and correct view of what the Academy is and should be, and did much to put it in its proper position in the framework of government."

On the conclusion of Campbell's term of office he and Mrs. Campbell returned to California, and after a short stay on Mount Hamilton made their home in San Francisco. They had a beautiful apartment overlooking the blue waters of the Golden Gate and the mountains beyond, where their many friends were wel-

[6] loc. cit. p. 7.

comed and hospitably entertained. Although he did not actively participate in scientific affairs at the time, Campbell took a general interest in current developments and viewed the astronomical scene with intelligence and satisfaction. He was in his middle seventies, and in failing health, though he seldom referred to his infirmities, and never permitted them to mar the pleasure of his guests; nevertheless they grew, and, in particular, he found himself losing the sight of his remaining eye. Without cause, other perhaps than that his memory was, in unimportant respects, not so good as it had been, he feared impairment of his reason, and was fearful lest he become a burden upon others; eventually his worry could not escape the observation of his friends, and it became to them a matter of concern. However, the last time I called upon him he was seemingly better than for a long time; he was bright and cheerful, with apparently not a care in the world. A few weeks later, on June 14, 1938, his friends, and the community, were shocked by his tragic death.

One who attempts to appraise the traits of character and other factors that contributed to Campbell's success must be struck by his extraordinary capacity for hard work. While he appreciated the value of relaxation and enjoyed active recreation, one does not recall ever to have seen him doing nothing, that is to say if he could help it. If there were ten minutes to spare, he could usually contrive to find some way of using them to advantage. A quality perhaps related to industry is perseverance, and he certainly had the capacity, once he had set his hand to a task, to sit tight and see it through. A factor contributing to the fullness of Campbell's career, second in potency to none, was the serenity of his domestic life. He was married to Elizabeth Ballard Thompson on December 28, 1892, shortly after he had established himself at the Lick Observatory. Mrs. Campbell and their three sons, Wallace, Douglas, and Kenneth, survive him. Mrs. Campbell was an ideal companion to her husband. She presided with dignity and charm over their home, and accompanied him on his many travels, even on the journey that led so far afield as the desolate "forty-mile beach" of western Australia, the site of the 1922 eclipse station. She served on all of his eclipse expeditions in the important capacity of chief of commisariat, and had the health and well being of her colleagues in her keeping; also she found time to join them in their scientific observations. Mrs. Campbell was and is a person of rich wisdom and unhurried judgments. That her counsel profoundly influenced the course of her husband's life none who had the privilege of knowing them will be likely to question. In commenting upon a life of great accomplishment one cannot but reflect upon a personality that provided probably its greatest inspiration.

Campbell was the recipient of many honors, and occupied various posts of distinction and responsibility. Among them are the following:

Trustee of the Carnegie Institution of Washington.

Lectureships:

Silliman Lecturer, Yale University, 1909-10; William Ellery Hale Lecturer, National Academy of Sciences, 1914; Halley Lecturer, Oxford University, 1925.

Honorary degrees:

M.S. University of Michigan, 1899.
Sc. D. University of Western Pennsylvania, 1900; University of Michigan, 1905; University of Western Australia, 1922; Cambridge University, 1925; Columbia University, 1928; University of Chicago, 1931.
LL.D. University of Wisconsin, 1902

Membership in scientific societies and organizations:

National Academy of Sciences, President 1931-35; American Philosophical Society, Vice President 1924-30; International Astronomical Union, President 1922-25; American Academy of Arts and Sciences; American Association for the Advancement of Science, President 1915; American Astronomical Society, President 1922-25; Die Astronomische Geselleschaft; Astronomical Society of the Pacific, President 1895 and 1910; Seismological Society of America.

Honorary membership in the following academies and organizations:

Royal Astronomical Society, London; Royal Academy of Sciences, Stockholm; Royal Academy of Sciences, Upsala; Society of Italian Spectroscopists, Rome; Royal Society of London; Madrid Academy of Sciences; Royal Society of Edinburgh; Russian Astronomical Society, Moscow; California Academy of Sciences, San Francisco; Royal Institution, London; Royal Astronomical Society of Canada; Institut de France (Paris Academy of Sciences); Bureau do Longitudes, Paris; Russian National Academy, Leningrad; Royal Italian Academy of Sciences (dei Lincei), Rome.

Decorations:

Commander of the Order of Leopold II, with gold insignia, Belgium, 1919; Officer of the Legion of Honor, with gold insignia, France, 1926; Commander of the Order of the Crown of Italy, with gold insignia, 1929.

Medals:

Paris Academy of Sciences, Lalande Medal, 1903; Royal Astronomical Society, London, Annual Medal, 1906; National Academy of Sciences, Washington, Draper Medal, 1906; Paris Academy of Sciences, Janssen Medal, 1910; Astronomical Society of the Pacific, Bruce Medal, 1915.

Sources of information: A scientific and personal association with Doctor Campbell of many years duration. This has been supplemented by a brief biographical sketch prepared by Doctor Campbell, and by a few letters from Mrs. Campbell. The *bibliography* was compiled by Doctor Campbell, and has been only lightly edited.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Astr. Nach. = Astronomische Nachrichten
Astron. and Astroph. = Astronomy and Astrophysics
Astron. Jour. = Astronomical Journal
Astroph. Jour. = Astrophysical Journal
L. O. Bull. = Lick Observatory Bulletin
Mem. Nat. Acad. Sci. = Memoirs, National Academy of Sciences
Pop. Astron. = Popular Astronomy
Pop. Sci. Mo. = Popular Science Monthly
Publ. L. O. = Publications of the Lick Observatory
Publ. A. S. P. = Publications of the Astronomical Society of the Pacific

BIBLIOGRAPHY OF WILLIAM WALLACE CAMPBELL

1888

1. Definitive Determination of the Orbit of Comet 1885 III. Astr. Nach., **120**, 49-58.

1889

2. Observations of Comet *b* 1889. Astron. Jour., **8**, 183-4; **9**, 7.
3. Elements and Ephemeris of Comet *b* 1889. Astron. Jour., **9**, 6, 37, 69, 94.
4. Ring-Micrometer Observations of Comet *c* 1888. Astron. Jour., **9**, 38-9.
5. Elements and Ephemeris of Comet *c* 1889. Astron. Jour., **9**, 46.
6. Elements of Comet *e* 1889. Astron. Jour., **9**, 119.

1890

7. Elements and Ephemeris of Comet *g* 1889. Astron. Jour., **9**, 136, 140.
8. Observations of Comet *g* 1889. Astron. Jour., **9**, 143-4.
9. Elements and Ephemeris of Comet *a* 1890. Astron. Jour., **9**, 184; **10**, 12-3, 45-6, 98.
10. Observations of Comet *a* 1890. Astron. Jour., **9**, 190; **10**, 15-6.
11. Observations of Comet *b* 1890. Astron. Jour., **10**, 54.

1891

12. Elements and Ephemeris of Comet *e* 1890. Astron. Jour., **10**, 134.
13. Corrections to Watson's Theoretical Astronomy. Publ. A.S.P., **3**, 87-91, 379 (See also p. 223 of same vol.)
14. A Handbook of Practical Astronomy for University Students and Engineers. The Inland Press, Ann Arbor, octavo, pp. 1-166 plus iii.

15. The Forms of Jupiter's Satellites (with J. M. Schaeberle). Publ. A.S.P., **3**, 355-8.
16. Observations of Markings on Jupiter's Third Satellite (with J. M. Schaeberle). Publ. A.S.P., **3**, 359-65.
17. Elements and Ephemeris of Comet *e* 1891. Publ. A.S.P., **3**, 378.

1892

18. New Elements and Ephemeris of Comet *e* 1891. Astron. Jour., **11**, 111-2.
19. The Reduction of Spectroscopic Observations of Motions in the Line of Sight. Astron. and Astroph., **11**, 319-25. Reprinted in Frost's translation of Scheiner's *Die Spectralanalyse der Gestirne,* pp. 338-51, 1894.
20. The Spectrum of Comet *a* 1892. Astron. Jour., **11**, 176; reprinted in Astron. and Astroph., **11**, 523.
21. The Spectrum of Comet *a* 1892. Astron. and Astroph., **11**, 698-700.
22. Nova Aurigae. Publ. A.S.P., **4**, 192.
23. Recent Observations of Nova Aurigae. Astron. and Astroph., **11**, 715-9.
24. Observations of the Occultation of Mars, Sept. 3, 1892. Publ. A.S.P., **4**, 194.
25. The Spectrum of Nova Aurigae in February and March, 1892. Astron. and Astroph., **11**, 799-811.
26. Recent Observations of Nova Aurigae (Sept. 8 to Oct. 13, 1892). Astron. and Astroph., **11**, 820-1.
27. The Spectrum of Nova Aurigae. Astr. Nach., **131**, 201-6.
28. New Elements and Ephemeris of Comet *c* 1892. Astron. Jour., **12**, 111.
29. The Motion of Nova Aurigae. Astron. and Astroph., **11**, 881-2; Astr. Nach., **131**, 205-6.
30. The Spectra of Holmes' and Brooks' Comets (*f* and *d* 1892). Astr. Nach., **131**, 211-2; Astron. and Astroph., **12**, 57.
31. Observations of Mars and His Satellites. Astron. Jour., **12**, 137-9.
32. Visual Magnitudes of Nova Aurigae. Publ. A.S.P., **4**, 225-7.
33. The Spectrum of Nova Aurigae. Publ. A.S.P., **4**, 231-47.
34. Comets of 1892 and Their Spectra. Publ. A.S.P., **4**, 248-50.
35. Observations of Nova Aurigae from Nov. 9 to Dec. 14, 1892. Astron. and Astroph., **12**, 149; also, Publ. A.S.P., **5**, 55, 1893.

1893

36. Notes on Some Recent Observations of Nova Aurigae. Astron. and Astroph., **12**, 417-9.
37. Miscellaneous Observations of Nova Aurigae. Publ. A.S.P., **5**, 73-9.
38. Comet Holmes. Publ. A.S.P., **5**, 93-4.

39. The Spectrum of Holmes' Comet. Publ. A.S.P., **5**, 99-100.
40. The Motion of the Solar System. Publ. A.S.P., **5**, 104-5.
41. The Visible Spectrum of Gamma Argus. Publ. A.S.P., **5**, 106.
42. The Spectrum of Gamma Argus. Astron. and Astroph., **12**, 555-6.
43. Spectrum of Comet *b* 1893. Astr. Nach., **133**, 149-52; Astron. and Astroph., **12**, 652-3.
44. Concerning the Nature of Nova Aurigae's Spectrum. Astr. Nach., **133**, 337-42; also, with 2-page Addendum, in Astron. and Astroph., **12**, 722-9.
45. Note Concerning the Accuracy of the Wave-Length Determinations in Nova Aurigae's Spectrum. Astr. Nach., **133**, 395-8.
46. The Spectrum of Comet *b* 1893. Astr. Nach., **133**, 149-52; Astron. and Astroph., **12**, 652-3.
47. The Hydrogen Atmosphere of the Wolf-Rayet Star BD +30°3639. Astron. and Astroph., **12**, 913-4; Astr. Nach., **134**, 133-4.
48. Preliminary Note on the Spectrum of the Orion Nebula. Astr. Nach., **134**, 211-2, 1894; Astron. and Astroph., **12**, 927.
49. Comparison of the New Star Spectrum with the Spectra of Five Well-Known Nebulae. Publ. A.S.P., **5**, 147-52.
50. The Panetary Nebula, SD —12°1172. Publ. A.S.P., **5**, 207.
51. Visible Spectrum of Comet *c* 1893. Publ. A.S.P., **5**, 208-10.
52. Star Spectra in Which Two or More of the Hydrogen Lines Are Bright. Publ. A.S.P., **5**, 228-9.
53. The Spectrum of Alcyone. Publ. A.S.P., **5**, 231.
54. Wave-Lengths of the Principal Lines in Nova Aurigae's Spectrum. Publ. A.S.P., **5**, 232.

1894

55. Observations of the New Star in Norma. Astr. Nach., **135**, 131-2; Astron. and Astroph., **13**, 311-2.
56. Note on the Spectra of Comets *b* and *c* 1893. Astron. and Astroph., **13**, 571-4.
57. Spectra of the Great Nebula in Orion and Other Well-Known Nebulae. Astron. and Astroph., **13**, 384-98, 494-501.
58. The Wolf-Rayet Stars. Astron. and Astroph., **13**, 448-76.
59. Note on the Variable Star, A.G.C. 22855. Astron. Jour., **14**, 110.
60. The Spectrum of Comet *b* 1894. Astron. Jour., **14**, 111.
61. Observations of the Transit of Mercury, Nov. 10, 1894. Astron. Jour., **14**, 148-9.
62. Note on the Spectrum of the Orion Nebula. Astron. and Astroph., **13**, 695-6.
63. Drawings of the Planet Mars. Publ. A.S.P., **6**, 171 plus two plates.
64. The New Star in Norma. Publ. A.S.P., **6**, 102-3.
65. An Explanation of the Bright Projections Observed on the Terminator of Mars. Publ. A.S.P., **6**, 103-12.

66. The Lick Observatory Photographs of Mars. Publ. A.S.P., **6,** 139-41.
67. The Spectrum of Mars. Publ. A.S.P., **6,** 228-36; reprinted in Astron. and Astroph., **13,** 752-60.
68. The Use of the Short-Focus Camera in Stellar Spectrum Photography. Astron. and Astroph., **13,** 857-8.
69. Is There Any Spectroscopic Evidence of an Atmosphere on Mars? San Francisco Chronicle, August 26.
70. Concerning an Atmosphere on Mars. Publ. A.S.P., **6,** 273-83.

1895

71. On Selecting Suitable Nights for Observing Planetary Spectra. Astron. and Astroph., **13,** 860-1, 1894; The Observatory, **18,** 50-1, (see also p. 121).
72. On Determining the Extent of a Planet's Atmosphere. Astroph. Jour., **1,** 85-6.
73. Recent Changes in the Spectrum of Nova Aurigae. Astroph. Jour., **1,** 49-51.
74. The New Star of 1892. Publ. A.S.P., **7,** 31-3.
75. Micrometer Observations of the Satellites of Mars. Astron. Jour., **15,** 1-8.
76. A Review of the Spectroscopic Observations of Mars. Astroph. Jour., **2,** 28-44.
77. A Spectrographic Determination of Velocities in the System of Saturn. Astroph. Jour., **2,** 127-35.
78. The Visible Spectrum of the Trifid Nebula. Astroph. Jour., **2,** 161-2.
79. Observations of the B Band in Stellar Spectra. Astroph. Jour., **2,** 163.
80. Note on the Spectrum of the Aurora. Astroph. Jour., **2,** 162. See also L. O. Bull., **5,** 47, 1908.
81. Observations of Nova (R) Normae. Astron. Jour., **15,** 100.
82. Observations of Nova (7787Q) Cygni. Astron. Jour., **15,** 100.
83. Stars Whose Spectra Contain Both Bright and Dark Hydrogen Lines. Astroph. Jour., **2,** 177-83.
84. A Determination of the Polar Diameter of Mars. Astron. Jour., **15,** 145-9.
85. The Irregular Waning of the North Polar Cap of Mars. Publ. A.S.P., **7,** 40-3.
86. A Brief Review of Frost's Translation of Scheiner's "Die Spectralanalyse der Gestirne." Publ. A.S.P., **7,** 71-6.
87. Address of the Retiring President of the Astronomical Society (of the Pacific). Publ. A.S.P., **7,** 81-8.
88. Note on the Melting of the Polar Caps of Mars. Publ. A.S.P., **7,** 292-3.
89. New Elements and Ephemeris of Comet *c* 1895. Astron. Jour., **16,** 7.

1896

90. Notes on Two Variable Stars. Astron. Jour., **16**, 24.
91. Observations of Comet *b* 1895. Astron. Jour., **16**, 69.
92. Observations of Comet *a* 1895. Astron. Jour., **16**, 70-1; and (with W. J. Hussey) **16**, 96.
93. Mars (a review of Percival Lowell's book, MARS, 1895). *Science*, **4**, 231-8; reprinted in Publ. A.S.P., **8**, 207-20. (See also *Science*, **4**, 358-9, 455-6.)
94. On the Determination of Planetary Diameters. Publ. A.S.P., **8**, 236-8.
95. Spectroscopic Notes: The Harvard Star, Z Centauri; The Spectrum of Mars; Comet 1895 IV; Comet 1895 V; Comet 1896 I; Comet 1896 III; Comet 1889-96; Nova Aurigae. Astroph. Jour., **5**, 233-42.

1897

96. Recent Observations of the Spectrum of Mars. *San Francisco Chronicle*, April 18; reprinted, in part, in Publ. A.S.P., **9**, 109-12.
97. On the Variations Observed in the Spectrum of the Orion Nebula. Astroph. Jour., **6**, 363-4.

1898

98. A General Account of the Lick Observatory-Crocker Eclipse Expedition to India. Publ. A.S.P., **10**, 127-40.
99. The Mills Spectrograph of the Lick Observatory. Astroph. Jour., **8**, 123-56.
100. Some Stars with Great Velocities in the Line of Sight. Astroph. Jour., **8**, 157-8.
101. The Variable Velocity of Eta Pegasi in the Line of Sight. Astroph. Jour., **8**, 159.
102. The Motion of Eta Cephei in the Line of Sight. Publ. A.S.P., **10**, 184-5.
103. The Purkinje Phenomenon and the Spectrum of the Orion Nebula. Astr. Nach., **147**, 393-6; Astroph. Jour., **8**, 317-9.
104. The Variable Velocity of Omicron Leonis in the Line of Sight. Astroph. Jour., **8**, 291.
105. The Variable Velocity of Chi Draconis in the Line of Sight. Astroph. Jour., **8**, 292.

1899

106. Three New Spectroscopic Binary Stars. Publ. A.S.P., **11**, 54-5.
107. Notes on the Spectrum of Omicron Ceti. Astroph. Jour., **9**, 31-6.
108. The Variable Velocity of Xi Geminorum in the Line of Sight. Astroph. Jour., **9**, 86.
109. On the Visual Spectrum of Nova Sagittarii. Astroph. Jour., **9**, 308-9.
110. The Variable Velocity of Iota Pegasi in the Line of Sight. Astroph. Jour., **9**, 310.

111. The Variable Velocity of Theta Draconis in the Line of Sight. Astroph. Jour., **9**, 311.
112. The Variable Velocities in the Line of Sight of Epsilon Librae, h Draconis, Lambda Andromedae, Epsilon Ursae Minoris, and Omega Draconis. Astroph. Jour., **10**, 178-9.
113. A Comparison of the Visual Hydrogen Spectra of the Orion Nebula and a Geissler Tube. Astroph. Jour., **9**, 312-16.
114. The Influence of the Purkinje Phenomenon on Observations of Faint Spectra. Astroph. Jour., **10**, 22-4.
115. The Spectroscopic Binary Capella. Astroph. Jour., **10**, 177.
116. The Variable Velocity of Alpha Ursae Minoris in the Line of Sight. Astroph. Jour., **10**, 180-3.
117. The Wave-Length of the Green Coronal Line, and Other Data Resulting from an Attempt to Determine the Law of Rotation of the Solar Corona. Astroph. Jour., **10**, 186-92.
118. Stars with Variable Velocities in the Line of Sight. Publ. A.S.P., **11**, 252-4.
119. The Variable Velocities of Beta Capricorni and Upsilon Sagittarii in the Line of Sight. Astroph. Jour., **10**, 241.
120. On the Variable Velocity of Polaris in the Line of Sight. Publ. A.S.P., **11**, 195-9.
121. The Elements of Practical Astronomy (an enlargement and revision of "A Handbook of Practical Astronomy, 1891," and successor thereto). The Macmillan Company, New York, 1899; octavo, 1-264 plus xii. Many later reprintings.

1900

122. Observations of the Second and Third Contacts at the Solar Eclipse of January 22, 1898, in India. Astron. Jour., **20**, 144-5.
123. The Determination of the Moon's Theoretical Spectrographic Velocity. Astroph. Jour., **11**, 141-3.
124. On the Probable Error of a Radial Velocity Determination. Astroph. Jour., **11**, 167-8.
125. Some Spectrographic Results Obtained at the Indian Eclipse by the Lick Observatory-Crocker Expedition. Astroph. Jour., **11**, 226-33.
126. The Temperature Control of the Mills Spectrograph. Astroph. Jour., **11**, 259-61.
127. The Variable Velocity of Beta Herculis in the Line of Sight. Astroph. Jour., **11**, 140.
128. Variable Velocities in the Line of Sight. The Observatory, **23**, 92-3.
129. The Crocker Expedition to Observe the Total Solar Eclipse of May 28, 1900 (with C. D. Perrine). Publ. A.S.P., **12**, 175-84.

130. James Edward Keeler (a biography and the bibliography). Astroph. Jour., **12**, 239-53; Pop. Sci. Mo., **58**, 85-91.

131. A List of Nine Stars Whose Velocities in the Line of Sight are Variable (with W. H. Wright). Astroph. Jour., **12**, 254-7.

132. The Triple Star Kappa Pegasi. Publ. A.S.P., **12**, 202-3.

133. The Visible Spectrum of Nova Aquilae. Astroph. Jour., **12**, 258.

134. An Atlas of Representative Stellar Spectra (a review of Sir William and Lady Huggins' book). Publ. A.S.P., **12**, 246-50.

1901

135. Determination of the Sun's Distance, from Observations of Eros. Science, **13**, 176-9; Publ. A.S.P., **12**, 251-4, 1900; reprinted in Pop. Astron., **9**, 88-91.

136. Some Stars with Large Radial Velocities. Astroph. Jour., **13**, 98-9.

137. The Motion of Xi Geminorum in the Line of Sight. Astroph. Jour., **13**, 90-7.

138. A Preliminary Determination of the Motion of the Solar System. Astroph. Jour., **13**, 80-9; reprinted in Publ. A.S.P., **13**, 51-60.

139. On Professor Keeler's Discovery and Observations of an Asteroid with the Crossley Reflector. Astr. Nach., **155**, 183-4.

140. On the Spectroscopic Binary Iota Pegasi. Astr. Nach. **155**, 249-50.

141. The Velocity of Alpha Persei in the Line of Sight. The Observatory, **24**, 199.

142. A List of Six Stars Whose Velocities in the Line of Sight are Variable. L. O. Bull., **1**, 22-3; reprinted in Astroph. Jour., **14**, 138-9.

143. Radial Velocities in the System of Delta Equulei. L. O. Bull., **1**, 23; reprinted in Astroph. Jour., **14**, 139-40.

144. Radial Velocities in the System of Polaris. L. O. Bull., **1**, 23; reprinted in Astroph. Jour., **14**, 140-1.

145. The Radial Velocity of Alpha Persei. L. O. Bull., **1**, 23-4; reprinted in Astroph. Jour., **14**, 141.

146. The Radial Velocity of Theta Ursae Majoris. L. O. Bull., **1**, 24; reprinted in Astroph. Jour., **14**, 141-2.

147. The Variable Velocity of Delta Orionis in the Line of Sight. L. O. Bull., **1**, 24; reprinted in Astroph. Jour., **14**, 142.

148. The Velocity of Groombridge 1830 in the Line of Sight. L. O. Bull., **1**, 24-5; reprinted in Astroph. Jour., **14**, 142-4.

149. Observations of the Spectroscopic Binary Eta Pegasi. L. O. Bull., **1**, 26; reprinted in Astroph. Jour., **14**, 202-3.

150. Observations of the Spectroscopic Binary Capella. L. O. Bull., **1**, 31-2; reprinted in Astroph. Jour., **14**, 261-3.

151. The D. O. Mills Expedition to the Southern Hemisphere. Publ. A.S.P., **13**, 28-9.

152. A list of Eight New Spectroscopic Binaries. Publ. A.S.P., **13**, 31-3.

153. Nova Persei. Publ. A.S.P., **13**, 65-8.
154. Some Stars with Large Radial Velocities. Publ. A.S.P., **13**, 72-3.
155. Visual Observations of Nova Aurigae. Publ. A.S.P., **13**, 127.
156. Observations of the Spectrum of Nova Persei (with W. H. Wright.) L. O. Bull., **1**, 44-56; reprinted in Astroph. Jour., **14**, 269-92.

1902

157. The Stars: A Study of the Universe (a brief review of Simon Newcomb's volume). Publ. A.S.P., **14**, 51-3.
158. Note on the Spectrum of Nova Persei (with W. H. Wright). Publ. A.S.P., **14**, 136.
159. A List of Six Stars Whose Velocities in the Line of Sight Are Variable. L. O. Bull., **1**, 158-9; reprinted in Astroph. Jour., **16**, 114-17.
160. The Mirror of the Crossley Reflector—a Correction. Astroph. Jour., **16**, 121.

1903

161. Problems in Astrophysics (a review of Miss A. M. Clerke's book). Astroph. Jour., **18**, 156-66.
162. A List of Five Stars Whose Velocities in the Line of Sight are Variable (with Heber D. Curtis). L. O. Bull., **2**, 126; reprinted in Astroph. Jour., **18**, 306-8.
163. A Brief Account of the D. O. Mills Expedition to Chile. Publ. A.S.P., **15**, 70-5. (See illustrations in **16**, opposite pp. 133 and 144, 1904.)
164. Report of Committee on Southern and Solar Observatories (Prepared by a special committee of three, Lewis Boss, Chairman, George E. Hale and W. W. Campbell, for the Carnegie Institution of Washington). Special publication of the Carnegie Institution, 1-70, December.

1904

165. Dedication of the Students' Observatory,—Introductory Remarks. Publ. A.S.P., **16**, 65-8.
166. The Crocker Eclipse Expeditions in 1905. L. O. Bull., **3**, 1-2; reprinted in Astroph. Jour., **20**, 235-6.
167. The Total Solar Eclipse of August 30, 1905. Pop. Sci. Mo., **65**, 97-108.
168. Castor a Quadruple Star. Publ. A.S.P., **16**, 260-3.

1905

169. The Variable Radial Velocity of Sirius. Astroph. Jour., **21**, 176-84; reprinted in L. O. Bull., **3**, 80-3.
170. A List of Nine Stars Whose Radial Velocities Vary (with Heber D. Curtis). Astroph. Jour., **21**, 185-90; L. O. Bull., **3**, 84-6.

171. On the Radial Velocities of Polaris, Eta Piscium, Epsilon Aurigae, and Beta Orionis (with Heber D. Curtis). Astroph. Jour., **21**, 191-3; L. O. Bull., **3**, 86-7.
172. An Address on Astrophysics (at the St. Louis International Congress of Arts and Science, 1904). Congress of Arts and Science, Houghton, Mifflin and Company, **6**, 446-469, 1906; Pop. Sci. Mo., **66**, 297-318.

1906

173. First Catalogue of Spectroscopic Binaries (with Heber D. Curtis). L. O. Bull., **3**, 136-46, 1905 (see also L. O. Bull., **4**, 98).
174. A List of Four Stars Whose Radial Velocities are Variable (with J. H. Moore). L. O. Bull., **4**, 68.
175. A List of Eight Stars Whose Radial Velocities are Variable (with J. H. Moore). L. O. Bull., **4**, 96-7.
176. The Radial Velocity of Polaris. L. O. Bull., **4**, 98; also Astroph. Jour., **25**, 59, 1907.
177. On the San Francisco Earthquake of 1906, April 18. Publ. A.S.P., **18**, 213-17; reprinted in The Observatory, **29**, 345-8.
178. The Lick Observatory-Crocker Eclipse Expedition to Spain (with C. D. Perrine). Publ. A.S.P., **18**, 13-36.
179. Two Stars Whose Velocities are Variable (with J. H. Moore). Publ. A.S.P., **18**, 137-8.
180. History of the Naming of Mount Hamilton. Publ. A.S.P., **18**, 225-6.
181. The Radial Velocity of Polaris. Publ. A.S.P., **18**, 307.
182. Seven New Spectroscopic Binaries (with J. H. Moore). Publ. A.S.P., **18**, 308-9.
183. Note on the Chile Earthquake of August 16, 1906. Publ. A. S.P., **18**, 313-4.

1907

184. The Solar Corona. Publ. A.S.P., **19**, 71-80.
185. Station Coordinates and Contact-Times for the Eclipse of August 30, 1905. L. O. Bull., **4**, 118-120.
186. The Results of an Effort to Determine Motion within the Solar Corona (with C. D. Perrine). L. O. Bull., **4**, 121.
187. Note on a Disturbed Region in the Corona of August 30, 1905 (with C. D. Perrine). L. O. Bull., **4**, 122.
188. A List of Six Stars Whose Radial Velocities Vary (with J. H. Moore). L. O. Bull., **4**, 161-2.
189. Two Stars Whose Radial Velocities are Variable (with J. H. Moore). L. O. Bull., **4**, 162.
190. Organization and History of the D. O. Mills Expedition to the Southern Hemisphere. Publ. L. O., **9**, (quarto), 5-12.
191. A List of Eight Stars Whose Radial Velocities are Variable (with J. H. Moore). Astroph. Jour., **25**, 54-6.

192. Eight Stars Whose Radial Velocities Vary (with J. H. Moore). Astroph. Jour., **26,** 292-5.

1908

193. The Crocker Eclipse Expedition of 1908 (Flint Island). L. O. Bull., **5,** 1-5.
194. Coronal Photographs with the Floyd Camera (Flint Island). L. O. Bull., **5,** 7-8.
195. Coronal Photographs with the Forty-Foot Camera (with Sebastian Albrecht, at Flint Island). L. O. Bull., **5,** 8-9.
196. The Spectrum of the Sun's Edge with the Moving-Plate Spectrograph (Flint Island). L. O. Bull., **5,** 10.
197. The Coronal Spectrum (with Sebastian Albrecht). L. O. Bull., **5,** 13-14.
198. A Disturbed Region in the Corona of January 3, 1908 (with Sebastian Albrecht). L. O. Bull., **5,** 36-7.
199. Eleven Stars Having Variable Radial Velocities. L. O. Bull., **5,** 61-3.
200. Eighteen Stars Whose Radial Velocities Vary. Publ. A.S.P., **20,** 293-4.
201. The Spectrum of Comet *d* 1907. Astroph. Jour., **28,** 229-36.
202. The Eclipse of January 3, 1908. Publ. A.S.P., **20,** 33-5.
203. The Crocker Eclipse Expedition of 1908 from the Lick Observatory, University of California. Publ. A.S.P., **20,** 63-86.
204. The Nature of an Astronomer's Work. The North American Review, June, 1908; reprinted, by special permission, in Publ. A.S.P., **20,** 251-60.
205. Comparative Power of the 36-inch Refractor of the Lick Observatory. Pop. Astron., **16,** 560-2.
206. The Partial Solar Eclipse of June 28, 1908. Publ. A.S.P., **20,** 233.
207. A Remarkable Star Stream in Taurus. Publ. A.S.P., **20,** 277-80.
208. The Spectrum of Comet *c* 1908 (with Sebastian Albrecht). L. O. Bull., **5,** 58-9. (See L. O. Bull., **5,** 64-5, 1909; also, Publ. A.S.P., **21,** 30-4, 1909.)

1909

209. Copy of Telegram Concerning the Spectrum of Mars. L. O. Bull., **5,** 146.
210. The Spectrum of Mars as Observed by the Crocker Expedition to Mt. Whitney. L. O. Bull., **5,** 149-56.
211. A Review of the Spectroscopic Observations of Mars. L. O. Bull., **5,** 156-64. (See also L. O. Bull., **5,** 164A, 1910.)
212. The Closing of a Famous Astronomical Problem. Pop. Sci. Mo., **74,** 494-503; reprinted, by special permission, in Publ. A.S.P., **21,** 103-15.
213. Note on the Spectrum of Mars. Science, **29,** 500.

214. Water Vapor in the Atmosphere of the Planet Mars. Science, **30,** 474-5.
215. The Return of Halley's Comet. Publ. A.S.P., **21,** 188-95.
216. On the Spectrum of Mars. Publ. A.S.P., **21,** 201-5.
217. Stars Whose Radial Velocities Vary (with Sebastian Albrecht). L. O. Bull., **5,** 174-6.
218. Note Concerning the Radial Velocity of Procyon. L. O. Bull., **5,** 178.
219. Note on the Radial Velocity of Polaris. L. O. Bull., **5,** 178.
220. The Spectrum of Comet *c* 1908 (with Sebastian Albrecht). Astroph. Jour., **29,** 84-87.
221. Eleven Stars Having Variable Radial Velocities. Astroph. Jour., **29,** 224-8.

1910

222. On the Spectrum of Mars as Photographed with High Dispersion (with Sebastian Albrecht). L. O. Bull., **6,** 11-16 (see also L. O. Bull., **6,** 16A).
223. Second Catalogue of Spectroscopic Binary Stars. L. O. Bull., **6,** 17-54 (see also L. O. Bull., **6,** 154, 1911).
224. Nine Stars Having Variable Radial Velocities. L. O. Bull., **6,** 57-8.
225. The Spectrum of Mars (letters by G. R. Agassiz and W. W. Campbell). Science, **32,** 407-8.
226. On the Spectrum of Mars as Photographed with High Dispersion (with Sebastian Albrecht). Science, **31,** 990-2.
227. Sir William Huggins, K.C.B., O.M. Publ. A.S.P., **22,** 149-63.
228. A Study of Spectroscopic Binary Stars. Publ. A.S.P., **22,** 47-63.

1911

229. Abstract of Some Results in the Motion of the Solar System and the Systematic Motions of the Stars. Publ. A.S.P., **23,** 57-63.
230. On the Motions of the Brighter Class B Stars. L. O. Bull., **6,** 101-24; extensive abstract and extracts in Publ. A.S.P., **23,** 85-108.
231. Some Peculiarities in the Motions of the Stars. L. O. Bull., **6,** 125-35.
232. Sixty-Eight Stars Whose Radial Velocities Vary. L. O. Bull., **6,** 140-9.
233. Note on the Radial Velocity of Gamma Piscium. L. O. Bull., **6,** 153.
234. Note on the Spectrum of 25 Orionis. L. O. Bull., **6,** 153.
235. Note on Radial Velocities of Nebulae. Astr. Nach., **188,** 345-6.

1912

236. Preliminary Radial Velocities of 212 Brighter Class A Stars. L. O. Bull., **7,** 19-29.
237. Two Stars Whose Radial Velocities are Variable. L. O. Bull., **7,** 102.
238. On the Masses of Spectroscopic Binary Stars. Publ. A.S.P., **24,** 79-81.

1913

239. Stellar Motions; with Special Reference to Motions Determined by Means of the Spectrograph (Silliman Lectures for the academic year 1909-10, in Yale University). Yale University Press; Oxford University Press; Henry Froude, London; octavo, 1-328 plus xi.

240. Some Recent Studies of Our Stellar System (First Annual Faculty Lecture, 1913). University of California Chronicle, **17**, 9-54, 1915.

241. International Meetings of Astronomers in Germany (Bonn, Hamburg, Bergedorf). Publ. A.S.P., **25**, 244-54.

242. The Radial Velocities of 915 Stars. L. O. Publ., **7**, 113-28.

243. A Nebula with Large Radial Velocity (with E. S. Haynes). Publ. A.S.P., **25**, 288-9.

1914

244. Note on Evidences of Rapid Convection in Stellar Atmospheres. L. O. Bull., **8**, 82.

245. Astronomical Activities of Professor George Davidson. Publ. A.S.P., **26**, 28-37.

246. Edward Singleton Holden (a biographic sketch). Publ. A.S.P., **26**, 77-87.

247. A Remarkable Thunder Storm. Publ. A.S.P., **26**, 105-6.

248. The Lick Observatory-Crocker Eclipse Expedition to Brovary, Russia (with Heber D. Curtis). Publ. A.S.P., **26**, 225-37.

249. A Brief History of Astronomy in California (a chapter in Eldredge's *History of California,* in five volumes). The Century History Company, New York; **5**, 231-271.

1915

250. The Pacific Association of Scientific Societies. Science, **41**, 637-8.

251. The Evolution of the Stars and the Formation of the Earth (Second Course of Lectures on the William Ellery Hale Foundation, National Academy of Sciences). Pop. Sci. Mo., **87**, 209-35, and continued in The Scientific Monthly, **1**, 1-17, 177-194, and 238-255.

252. Science and Civilization (Address as President, American Association for the Advancement of Science, San Francisco meeting, August, 1915). Science, **42**, 227-38.

253. On Atmospheric Conditions Required for Astronomical Observation. Publ. A.S.P., **27**, 65-70.

254. The Spectroscopy of the Extreme Ultra-Violet (a review of Theodore Lyman's volume). Publ. A.S.P., **27**, 138-41.

255. Radial Velocities of the Planetary and Irregular Nebulae (with J. H. Moore). Publ. A.S.P., **27**, 240-2.

256. Observed Rotations of Planetary Nebulae (with J. H. Moore). Publ. A.S.P., **27**, 245-7.

1916

257. The Wave-Length of the Green Nebular Lines N_1 and N_2 (with J. H. Moore). Publ. A.S.P., **28**, 83-4; L. O. Bull., **9**, 6-9.
258. Is the Crescent Form of Venue Visible to the Naked Eye? Publ. A.S.P., **28**, 85-6.
259. What We Know about Comets (Retiring Address of First President of the Pacific Division of the American Association for the Advancement of Science, San Diego, August, 1916). The Scientific Monthly, **3**, 521-46. (Also given as the Second Adolfo Stahl Lecture, San Francisco, December, 1916.) The Adolfo Stahl Lectures in Astronomy, octavo, 25-51, 1919.
260. Edward Singleton Holden, 1846-1914 (a biography and the bibliography). Biographical Memoirs, National Academy of Sciences, **8**, 347-72.
261. On the Rotation of the Planetary Nebula N.G.C. 6572 (with J. H. Moore). Publ. A.S.P., **28**, 120-1.
262. Note on the Relative Velocities Observed within Some of the Planetary Nebulae (with J. H. Moore). Publ. A.S.P., **28**, 119-20. See also Addendum in Publ. A.S.P., **28**, 213-4.
263. A Catalogue of the Meteorites of North America; Meteorites: Their Structure, Composition and Terrestrial Relations (a brief review of two volumes by Farrington). Publ. A.S.P., **28**, 139-45.
264. Note on the Spectral Type and Radial Velocity of Barnard's Proper-Motion Star (with J. H. Moore). Publ. A.S.P., **28**, 207-8.
265. On the Rotation of Some Planetary Nebulae (with J. H. Moore). L. O. Bull., **9**, 1-5.
266. On the Radial Velocity of Beta Ursae Majoris (with Adelaide M. Hobe). L. O. Bull., **9**, 22-7.
267. On Systematic Errors in the Measured Intervals between Close Lines. L. O. Bull., **9**, 28-9.
268. An Error in Radial Velocity Observations Arising from Non-Uniform Slit Illumination. L. O. Bull., **9**, 30-1.
269. On the Observed Rotations of Planetary Nebulae (with J. H. Moore). Publ. A.S.P., **28**, 283-5.
270. Note on the Spectrum of the Nebula N.G.C. 7293 (with J. H. Moore). Publ. A.S.P., **28**, 286.
271. The Solar System (the First Adolfo Stahl Lecture, given under the auspices of the Astronomical Society of the Pacific). Publ. A.S.P., **28**, 222-46, 1916; also, with some minor modifications, in The Adolfo Stahl Lectures in Astronomy, octavo, 1-25, 1919.

1917

272. The Unification of the Civil and Astronomical Time System. Publ. A.S.P., **29**, 249-53.

273. Some of the Fundamentals of Research. Transactions of the Commonwealth Club of California, **12**, 71-80.
274. Some Observations of Aurorae at Mount Hamilton. Publ. A.S.P., **29**, 218-9.
275. Four Nebulae with Bright-Line Spectra (with J. H. Moore). Publ. A.S.P., **29**, 54-5.
276. Spectrographic Observations of Rotation in the Planetary Nebula N.G.C. 7026 (with J. H. Moore). Publ. A.S.P., **29**, 55-6.
277. On the Rotation of the Nebula Jonckheere 320 (with J. H. Moore). Publ. A.S.P., **29**, 56.
278. On the Forms of Spectral Lines Observed in the Planetary Nebulae N.G.C. 7662 and N.G.C. 2392 (with J. H. Moore). Publ. A.S.P., **29**, 133-5.
279. A Remarkable Coincidence. Science, **46**, 36-7; reprinted in Publ. A.S.P., **29**, 219-21. See also The Observatory, **26**, 293-4, 1903.
280. The Nebulae (Address of retiring President American Association for the Advancement of Science). Science, **45**, 513-48.

1918

281. Kaiser Wilhelm as a Pillager in Boxer (Rebellion) Days. N.Y. Times Magazine, January 6; reprinted in San Francisco Examiner, January 20.
282. The Spectrum and Radial Velocity of the Spiral Nebula N.G.C. 4151 (with G. F. Paddock). Publ. A.S.P., **30**, 68-9.
283. The Problem of Mars. Publ. A.S.P., **30**, 133-46.
284. The Crocker Eclipse Expedition from the Lick Observatory, University of California, June 8, 1918. Publ. A.S.P., **30**, 219-40.
285. The Wave-Length of the Green Coronium Line (with J. H. Moore). Publ. A.S.P., **30**, 348-9.
286. Bright-Line Spectrum of the Corona (with J. H. Moore). Publ. A.S.P., **30**, 349-51.
287. Eight Stars with Variable Radial Velocity. Publ. A.S.P., **30**, 351-3.
288. The Total Solar Eclipse of June 8, 1918,—Position of Observing Station and Times of Contacts. L. O. Bull., **10**, 1-3.
289. The Total Solar Eclipse of June 8, 1918,—The Spectrum of the Solar Corona (with J. H. Moore). L. O. Bull., **10**, 8-14.
290. The Spectrographic Velocities of the Bright-Line Nebulae (with J. H. Moore). Publ. L. O., **13** (quarto), 77-183.
291. International Relations in Science (address delivered in the Conference on International Relations, at the Semi-Centenary Celebration of the Founding of the University of California, held in Berkeley, April, 1918). Semicentennial Publications Univ. Cal., 390-413.

1919

292. The Lick Observatory Community in War Service. Publ. A.S.P., **30**, 353-7. See also San Jose Mercury-Herald, April 23.
293. Notes on Furuhjelm's Observations of the Coronal Spectrum on August 21, 1914 (with J. H. Moore). L. O. Bull., **10**, 21.
294. Stars Whose Spectra Are Composite. Publ. A.S.P., **31**, 37-8.
295. The Variable Velocity of Beta Cygni. Publ. A.S.P., **31**, 38-9.
296. Edward Charles Pickering, 1846-1919. Publ. A.S.P., **31**, 73-6.
297. Shall We Reform the Calendar? Publ. A.S.P., **31**, 150-7.
298. Suggested Procedure for Standardizing Radial Velocity Results (abstract). Publ. A.S.P., **31**, 190-1.
299. The International Research Council and the International Astronomical Union. Publ. A.S.P., **31**, 249-56.

1920

300. Notes on the Problem of the Origin of the Lunar Craters. Publ. A.S.P., **32**, 126-38.
301. Notes on the Binary Star Sirius. Publ. A.S.P., **32**, 199-200.
302. Sir Joseph Norman Lockyer, 1836-1920. Publ. A.S.P., **32**, 265-8.
303. Concerning Our Relations with the Teutonic Scientists. Science, **52**, 109.
304. The Daily Influences of Astronomy (address at Dedication of the Warner and Swasey Observatory, Cleveland). Science, **52**, 543-52; reprinted in the Smithsonian Institution Report for 1921, 139-152.

1921

305. The Aurora Borealis of May 14, 1921. Publ. A.S.P., **33**, 164-7.
306. Observations of an Unidentified Object Seen near the Sun on August 7, 1921. Publ. A.S.P., **33**, 258-60.
307. A Defense of Professor Newcomb's Logic. Science, **54**, 113.
308. If You Had Your Life to Live over, What Would You Choose as Your Life Work? San Jose Mercury-Herald, October 26.
309. The Radial Velocity of Planetary Nebula I.C. 2003 (with J. H. Moore). Publ. A.S.P., **33**, 62.

1922

310. Three Probable Spectroscopic Binaries. Publ. A.S.P., **34**, 169.
311. (Forty-Nine) Stars Whose Radial Velocities Vary. Publ. A.S.P., **34**, 167-9.

1923

312. The Geographical Distribution of Memberships in the National Academy of Sciences. Science, **58**, 324-25, and **68**, 342-43, 1928.
313. The Total Eclipse of the Sun, September 21, 1922. Publ. A.S.P., **35**, 11-44.

314. The Fire in California (Berkeley, September 17, 1923). Science, **58**, 348-9.
315. Observations on the Deflection of Light in Passing through the Sun's Gravitational Field, Made during the Total Solar Eclipse of September 21, 1922 (with R. J. Trumpler). L. O. Bull., **11**, 41-54; abstract of this paper in Publ. A.S.P., **35**, 158-63.
316. The Axis of Symmetry of the Polar Streamers in the Solar Corona (with J. H. Moore and Robert H. Baker). Publ. A.S.P., **35**, 163-6.

1924

317. Simon Newcomb (a biographical memoir). Mem. Nat. Acad. Sci., **17**, 1-18.
318. Universities and the Truth (Inaugural Address as President of the University of California). Univ. Cal. Chronicle, **26**, 342-55.

1926

319. Do We Live in a Spiral Nebula? (Address of retiring President of the American Astronomical Society) Science, **63**, 263-7; reprinted in Publ. A.S.P., **38**, 75-85.
320. Addresses in Dedication of the New Campus and New Buildings of the University of California at Los Angeles. Special pamphlets of related addresses, University of California Press: 13-24; and 59-62, 65, 78, and 84-6, 1930.
321. The Elements of the Solar Motion Derived from Stars of Visual Magnitudes Brighter than 5.51 (abstract with J. H. Moore). Publ. A.S.P., **38**, 255.

1928

322. Observations Made with a Pair of Five-Foot Cameras on the Light Deflections in the Sun's Gravitational Field at the Total Solar Eclipse of September 21, 1922 (with R. J. Trumpler). L. O. Bull., **13**, 130-60.
323. Note on the Spectrum of Mars. The Observatory, **51**, 322-3.
324. Newton's Influence upon the Development of Astrophysics (address on the 2-day program, in New York City, 1927, in the bi-centenary evaluation of the influence of Sir Isaac Newton's contributions to science). Special publication No. 1 of the History of Science Society, 67-86; the Williams and Wilkins Company, Baltimore.
325. Radial Velocities of Stars Brighter than Visual Magnitude 5.51, as Determined at Mount Hamilton and Santiago, with collaboration of Joseph H. Moore, and assistance of other Members of the Lick Observatory Staff. Publ. L. O., **16**, (quarto), 1-399 plus xlv.

1929

326. On the Probable Errors of Some Stellar Radial Velocities Observed at the Cape of Good Hope and at Mt. Hamilton and Santiago. Monthly Notices Royal Astronomical Society, **89**, 506-518.
327. Address at Celebration of Twenty-Fifth Anniversary of Beginning of Research Activity by Carnegie Institution of Washington. On board non-magnetic ship *Carnegie*, San Francisco Harbor, August 26, 1929. Science, **70**, 245-7.

1930

328. What Price "Best Football"? The Argonaut, San Francisco, March 1.

1931

329. Introduction (to Menzel's paper, A Study of the Solar Chromosphere). Publ. L. O., **17**, (quarto), i-vi.
330. Address in Honor of Professor Albert Einstein (in California Institute of Technology, Pasadena, January, 1931). Science, **73**, 377-8.

1933

331. The National Academy of Sciences (Annual Address by the President, April, 1933). Science, **77**, 549-52.
332. Who Shall Go to College? (Address at Carnegie Institute of Technology, in Celebration of 98th anniversary of Andrew Carnegie's birth.) The Carnegie Magazine, Pittsburgh, 197-201.

1934

333. Address of the President of the National Academy of Sciences (April, 1934). Science, **79**, 391-6.
334. The National Academy of Sciences, Address of the President (Cleveland, November, 1934). Science, **80**, 535-7.

1935

335. Address of the President of the National Academy of Sciences (April, 1935). Science, **81**, 409-14.

1936

336. Simon Newcomb: a Tribute to His Personality and His Accomplishments. (Address at the unveiling of the bust of Simon Newcomb in the Hall of Fame in New York University, May 28, 1936.) Science, **84**, 165-9.

1937

337. Ambrose Swasey, 1846-1937. Publ. A.S.P., **49**, 179-185.