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SETH CARLO CHANDLER, JR.

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A Biographical Memoir by

W.E. CARTER AND M.S. CARTER

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September 16, 1846–December 31, 1913

BY W. E. CARTER AND M. S. CARTER

SETH CARLO CHANDLER, JR., IS best remembered for his research on the variation of latitude (i.e., the complex wobble of the Earth on its axis of rotation, now referred to as polar motion). His studies of the subject spanned nearly three decades. He published more than twenty-five technical papers characterizing the many facets of the phenomenon, including the two component 14-month (now referred to as the Chandler motion) and annual model most generally accepted today, multiple frequency models, variation of the frequency of the 14-month component, ellipticity of the annual component, and secular motion of the pole. His interests were much wider than this single subject, however, and he made substantial contributions to such diverse areas of astronomy as cataloging and monitoring variable stars, the independent discovery of the nova T Coronae, improving the estimate of the constant of aberration, and computing the orbital parameters of minor planets and comets. His publications totaled more than 200.

Chandler's achievements were well recognized by his contemporaries, as documented by the many prestigious awards he received: honorary doctor of law degree, DePauw University; recipient of the Gold Medal and foreign associate of the Royal Astronomical Society of London; life member of the Astronomische Gesellschaft; recipient of the Watson Medal and fellow, American Association for the Advancement of Science; and fellow, American Academy of Arts and Sciences. Considering this prominence, one might ask why it is just now, three quarters of a century after his death, that Chandler's biographical memoir is being written. This is actually two questions: "Why was it not written many years ago by a contemporary?" and "Why write it now, so many years after his death?"

Unfortunately, the answer to the first question is probably related to certain controversies in which Chandler became involved. Chandler's formal education reached only graduation from high school and he had virtually no theoretical background in astronomy or physics. However, he was a talented observer and an extraordinarily adroit computer, and he reported his observational and computational results with total disregard for conflicting accepted theory. As associate editor and later editor of the *Astronomical Journal,* Chandler had little difficulty publishing and often included extensive commentaries in his technical papers. Chandler's comments undoubtedly proved particularly irritating to certain individuals simply because of his close association with Benjamin Pierce, B. A. Gould, and A. D. Bache. Just a few decades earlier these three scientists had joined forces in a highly publicized dispute over an attempt to develop a national observatory that ended in failure and left many personal animosities (James, 1987).

The answer to the second question (Why now?) is more certain and pleasant. The recent development of very long baseline interferometry (VLBI) has improved the measurement of Earth orientation, including polar motion, length of day, universal time (UT1), precession, and nutation by two orders of magnitude. New information about the interior structure of the Earth, motions of the plates that form the surface of the Earth, and improved understanding of the interactions among the oceans, atmosphere, and solid Earth have been derived from the highly accurate VLBI observations (Carter and Robertson, 1986). But contemporary researchers using high-speed digital computers and analysis techniques not even known in Chandler's day have found it difficult to develop a better model of polar motion. Recognition of the sheer volume of the computations that Chandler performed by hand and the completeness with which he was able to characterize the complexities of polar motion (not to mention the vast quantities of computations in his research of variable stars, comets, and minor planets) has brought a renewed appreciation of his achievements (Mulholland and Carter, 1982; Carter, 1987). His work has clearly withstood the test of time, and the minimal documentation afforded by this biographical memoir is long overdue.

BIOGRAPHICAL INFORMATION

Seth Carlo Chandler, Jr., was an eighth-generation American born in Boston, Massachusetts, on September 16, 1846. His father was a member of the firm of Roby and Company, dealers in hay, coal, and other produce. Seth Carlo, Jr., was one of six children. He attended the English High School at Boston, graduating in 1861. During his last year in high school Chandler became associated with Benjamin Pierce, of the Harvard College Observatory, for whom he performed mathematical computations. Upon graduating he became a private assistant to B. A. Gould, one of the best known American astronomers of that time. Gould was assisting the U.S. Coast Survey in developing improved procedures for the determination of astronomic longitude, and in 1864 Chandler joined the survey as an aide.

In 1866 Chandler was assigned to an astronomic survey party, where he served as an observer and performed computations. He participated in a historic determination of the astronomic longitude at Calais, Maine, in which the new trans-Atlantic cable was used to relate the local clock to the master clock at the Royal Greenwich Observatory, England. His party also traveled by ship to New Orleans to make longitude determinations, again using telegraph signals to synchronize the local clock with the Coast Survey's master clock. It was an exciting period in geodetic astronomy and the young Mr. Chandler had the opportunity to learn the latest computational techniques, develop his observational skills, and acquaint himself with state-of-the-art instrumentation.

When Chandler fell in love with Carrie Margaret Herman, he decided to leave the Coast Survey and accept a position in New York City, as an actuary with the Continental Life Insurance Company. In October 1870 they were married and during the next six years their first three daughters were born: Margaret Herman in 1871; Caroline Herman in 1873; and Mary Cheever in 1876. Chandler corresponded regularly with his old mentor B. A. Gould, who had moved to Argentina to establish the Cordoba Observatory. With Gould's encouragement Chandler published his first technical paper, on the development of an analytical expression for computing a person's life expectancy from his current age, an alternate method to actuarial tables.

In 1876 Chandler moved his young family to Boston, where he continued his actuarial work as a consultant to the Union Mutual Life Insurance Company of Boston. In 1880 the Chandlers' fourth daughter, Elizabeth, was born. The same year Chandler renewed his association with the Harvard College Observatory, and in 1881 moved into a brand new house in Cambridge, within a short walking distance of the observatory. Three more daughters were to be born while the Chandlers lived on Craigie Street: Abbie in 1883; Eunice in 1888; and Helen Osgood in 1893. Chandler spent many of the most enjoyable hours of his life at the eyepiece of his telescope, which was mounted in a cupola atop the roof of this house. It was also from this house that he carried on the duties of associate editor of the *Astronomical Journal,* while B. A. Gould was editor, and later as editor after Gould's death. He used his own funds to help continue to publish the journal during difficult financial periods. In 1909 he turned the editorship over to Lewis Boss, but continued to serve as an associate editor.

When his father died in 1888 Chandler purchased his grandfather's place near Strafford, Vermont, and built a new summer home on the site. The Chandlers spent many relaxing times at their summer home. As a hobby Chandler designed and built model sailboats, which he raced on a small spring-fed pond on the front lawn. He relished the task of computing improved shapes for the hulls and was quite proud of his achievements.

In 1904 the Chandlers moved to a new home in the small town of Wellesley Hills, today a residential suburb of Boston, where he died on December 31, 1913. The Chandler homes in Cambridge, Wellesley Hills, and Strafford all are still standing, and the latter two are still owned by his descendants.

INVENTING THE ALMUCANTAR

While Chandler worked at the Coast Survey he used an instrument called a zenith telescope to determine the astronomical latitude and longitude of stations. This instrument was equipped with spirit (bubble) levels to reference the readings to the local vertical. Level vials with sensitivities of 1-2 seconds of arc per division were, and even today can be, quite finicky, changing sensitivity and behavior with temperature, age, stresses from mounts, and other unknown causes. Chandler set out to develop an instrument for determining astronomic latitude free of these leveling problems. His goal was to build an instrument that would automatically be aligned very precisely with the local vertical by the force of gravity.

Chandler considered two possible approaches: suspending the instrument like a pendulum, and floating it on mercury. He tested instruments of both designs, concluding that the flotation approach presented lesser mechanical problems. His next step was to have a small (45 millimeter diameter objective lens), relatively inexpensive instrument built. He was quite pleased with the performance of this first instrument, concluding from his analysis of observational data that "its accuracy seemed to be limited by its optical rather than its mechanical capacity" (Chandler, 1887). Encouraged by this success, he designed the larger aperture (100 millimeter diameter objective lens) instrument shown in Figure 1. The rectangular structure at one end of the horizontal axis was the mercury floatation bearing that kept the telescope constantly pointed to any angle of elevation set by the observer. The circle traced out in the sky when the instrument was rotated in azimuth (i.e., a small circle parallel to the horizon) is called an almucantar, and Chandler adopted this as the name of his new instrument.

By the time that the full scale Almucantar was completed Chandler had moved to Cambridge, and he immediately mounted the instrument on a pier on the grounds of the Harvard Observatory, near the main dome. During the period from May 1884 through June 1885 Chandler used the Almucantar to make latitude determinations on more than fifty nights. He carefully reduced the observations and published the resulting time series, pointing out that the values "exhibited a decided and curious progression throughout

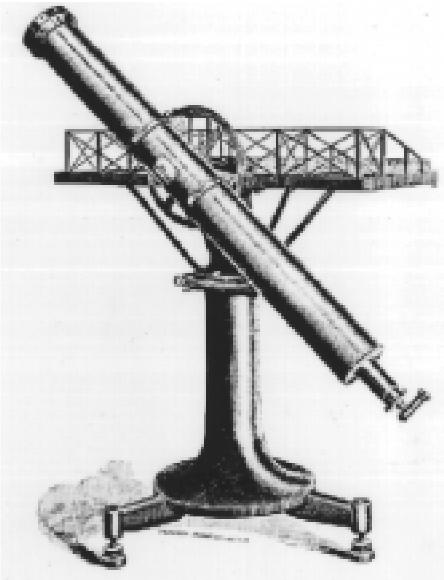

FIGURE 1. Sketch of the Almucantar used by Chandler to detect polar motion.

the series" for which he could identify no instrumental or personal cause (Chandler, 1887 and 1891a).

DISCOVERY OF POLAR MOTION

About 1765 Leonhardt Euler, a Swiss mathematician studying the dynamics of rotating fluid bodies, developed equations that suggested the Earth might wobble slightly about its axis of rotation. Such a wobble (free nutation) would result in periodic variations of the astronomic latitudes of all points on Earth. The expected period of the variation of latitude was approximately ten months. Several astronomers attempted to detect the phenomenon during the succeeding century, without success.

In 1888 German astronomer Friedrich Küstner (1888) published the results of his research on the constant of aberration, reporting that his analysis indicated that the latitude of the Berlin Observatory had changed during the period of the observing campaign. Küstner's observations were made during the same period as Chandler's Almucantar observations (i.e., 1884-85), but were not continuous enough to detect any periodicity in the variation of latitude. However, he argued strongly that the apparent change in latitude was real and his evidence was sufficiently convincing that the International Geodetic Association (now the International Association of Geodesy) organized a special observational campaign to verify his discovery. Küstner subsequently refined his analysis, finding a total variation in latitude of 0.5 seconds of arc, but giving no value of the period or direction of the motion of the pole (Küstner, 1890).

Chandler reexamined his Almucantar observations, as well as more recent observations made in Berlin, Prague, Potsdam, and Pulkova, and found a periodic variation of latitude, with a total range of about 0.7 seconds of arc and a period of 427 days, approximately 14 months (Chandler, 1891a and 1891b). The 40 percent discrepancy between the 305-day period predicted by theory and the 427-day observed period was quickly explained by Simon Newcomb as being the consequence of the "fluidity of the oceans" and the "elasticity of the Earth" (Newcomb, 1891).

There was some level of disagreement within the scientific community, which continues today, as to who should be credited with the discovery of polar motion, Küstner or Chandler. When the Royal Astronomical Society of London awarded Chandler the Gold Medal, it specifically made note of Küstner's contribution to the discovery, and many scientists (particularly European scientists) continue today to credit Küstner. However, the 14-month wobble of the pole is universally referred to as the Chandler motion, and there is no argument that Chandler illuminated the complex nature of the phenomenon, dominating the subject for decades.

LEARNING THE COMPLEXITIES OF POLAR MOTION

Chandler continued to analyze historical observations and in 1892 (Chandler, 1892a) reported that it appeared the period of the polar motion had changed, increasing from approximately twelve months to fourteen months, during the previous century. Newcomb (1892) responded: "The question now arises how far we are entitled to assume that the period must be variable. I reply that, perturbations aside, any variation of the period is in such direct conflict with the laws of dynamics that we are entitled to pronounce it impossible." Chandler (1892b) vigorously defended his analysis, pointing out that the accepted theory had already been modified once to agree with the observations and suggesting that the new theory might still be incomplete. He continued his analysis of the observations without regard to theoretical constraints, but soon discarded the model that included a secular variation in the period of the free nutation in favor of a model consisting of two periodic components, the 427-day term and a superimposed 365-day (annual) term (Chandler, 1892c). The annual motion could easily be attributed to seasonal relocations of the masses of the atmosphere, ground water, and snow cover.

There seems to be no record of Chandler ever revealing just how he had thought to investigate a two-component polar motion model, but it might well have been triggered by the results of a study made by his old friend B. A. Gould of variations of the latitude at the Cordoba Observatory (Gould, 1892). Gould found that he could detect the 14-month variation in the latitude that Chandler had "shown to exist at other places," only after subtracting an annual variation. He concluded that "in the absence of any indication as to its (the annual term's) origin, it may be attributed to instrumental causes, or to terrestrial ones." Chandler did not refer to Gould's results in defending the reality of the annual component in the variation of latitude. Rather, he argued that it was highly unlikely that seasonal variations in temperature would affect the measurements from observatories located at nearly equal latitudes but widely differing longitudes, in just such a way as to yield a consistent phase for the annual term. And, since such was the case for several observatories located in the northern hemisphere, "We may dismiss forever the bugbear which undoubtedly led many to distrust the reality of the annual component . . ." (Chandler, 1893).

SECULAR MOTION OF THE POLE

During the very same period that Chandler was doing the laborious computations required for him to formulate his two-component model of polar motion, and to use the model to correct historical observations (a subject to which we will return later), he also became embroiled in an argument with George C. Comstock concerning the latter's claim to have detected a secular drift of the pole (Comstock, 1892). There is not space to go into the details here, but Chandler showed that the rather large secular motion suggested by Comstock, 0.044 seconds of arc per year, was simply not supported by existent observations. He concluded that any secular motion must indeed be no larger than about one-tenth of that amount. The best estimate of the secular motion today, based on more than eighty years of observations made by the International Latitude Service, is about 0.003 seconds of arc per year in a direction roughly 130 degrees different from Comstock's model, but consistent with Chandler's bound.

RE-REDUCING HISTORICAL OBSERVATIONS

The Almucantar proved to be a very accurate instrument, as evidenced by Chandler's detection of polar motion from only thirteen months of observations, but it did not represent a fundamental technological breakthrough. Optical-mechanical instrumentation of essentially equal quality had been used for astronomical observations for well over a century. Chandler was quite aware of this and rather than mounting a new observational program of his own, or waiting for new observations to become available from other sources, he spent much of his energy re-reducing existing data, deriving some remarkable results. For example, by re-reducing zenith-tube observations made by the British astronomer Samuel Molyneux and zenith-sector observations made by the British astronomer James Bradley nearly two centuries earlier, Chandler was able to determine polar motion values for the period 1726 to 1731. Figure 2 is a plot of the results (Chandler, 1901c). In reporting this work Chandler recounted how Bradley had noticed anomalies in the observations that he had "unsuccessfully endeavored to trace to an instrumental source." It seems that Bradley had become concerned about a rapid change in the observed latitude between March and September 1728, and performed tests to determine if this was caused by the replacement of a wire on the plummet used to check the collimation of his telescope. From Chandler's vantage point (i.e., knowing the nature of polar motion) it was clear that the variation in the latitude had been quite real. He exclaimed, "So near did Bradley come to the discovery of the polar motion! Thus coincidentally can we now trace our knowledge of it to the same immortal work that gave us the aberration and nutation."

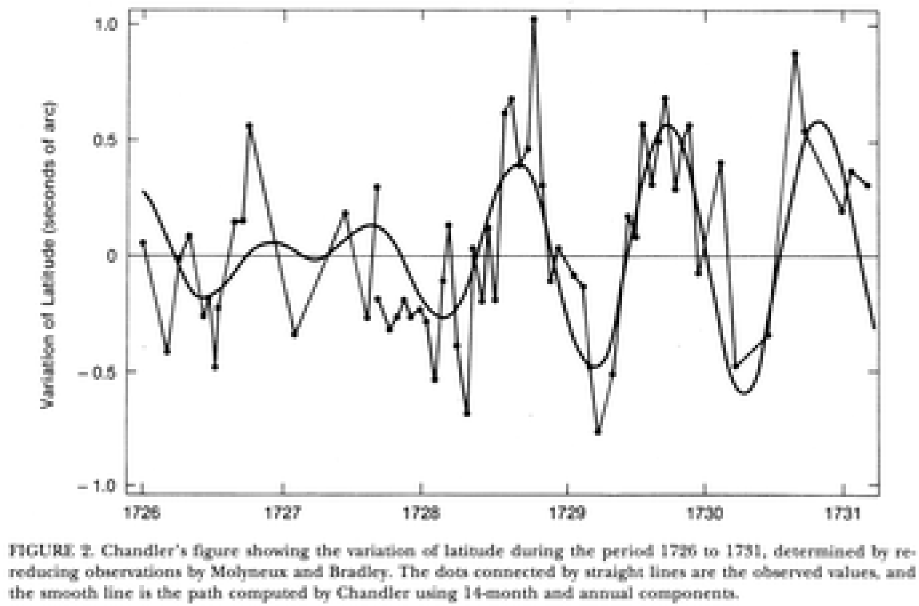

FIGURE 2. Chandler's figure showing the variation of latitude during the period 1726 to 1731, determined by re-reducing observations by Molyneux and Bradley. The dots connected by straight lines are the observed values, and the smooth line is the path computed by Chandler using 14-month and annual components.

FROM HISTORICAL RESULTS TO PREDICTIONS

Chandler continued to reduce and analyze historical observations, eventually piecing together thirty-seven short series from various observatories to form a nearly continuous record of polar motion beginning in 1820. As he refined his analysis he became convinced that the 14-month motion was not a simple, single-frequency oscillation, but was itself a complex motion involving two or more components. In 1901 he announced the discovery of a 436-day component that was considerably smaller than the 428-day component, but whose reality was "beyond reasonable doubt" (Chandler, 1901a). The beating of two components of such nearly equal frequencies but disparate amplitudes would generate a very distinctive pattern in the motion of the pole. Chandler described the effect as follows: "These fluctuations are embraced in a cycle of about 57 periods, or 67 years. (The period) . . . remains during five-sixths of the cycle between its mean value and the upper limit, or between 428.5 and 431.4 days; then suddenly shortens to minimum, 415 days, and immediately rapidly lengthens. Similarly the variations of radius of motion are singularly asymmetrical." Figure 3 is a copy of Chandler's sketch in which he plotted the observed motions of the pole and the motion calculated from his model (Chandler, 1901b). Based on these findings Chandler predicted "We shall soon have a . . . test of the law in its operation on the period which . . . ought to shorten to the minimum value, 415 days, within the next few years. Of course, an accurate prediction cannot be made as to when this interesting phase will become perceptible, because the length of the harmonic cycle, which depends on the difference of the two component periods, is imperfectly defined by existing observations." Even with this caveat, Chandler had taken a bold step in predicting the occurrence of such a pronounced variation in the motion of the pole. His pre-

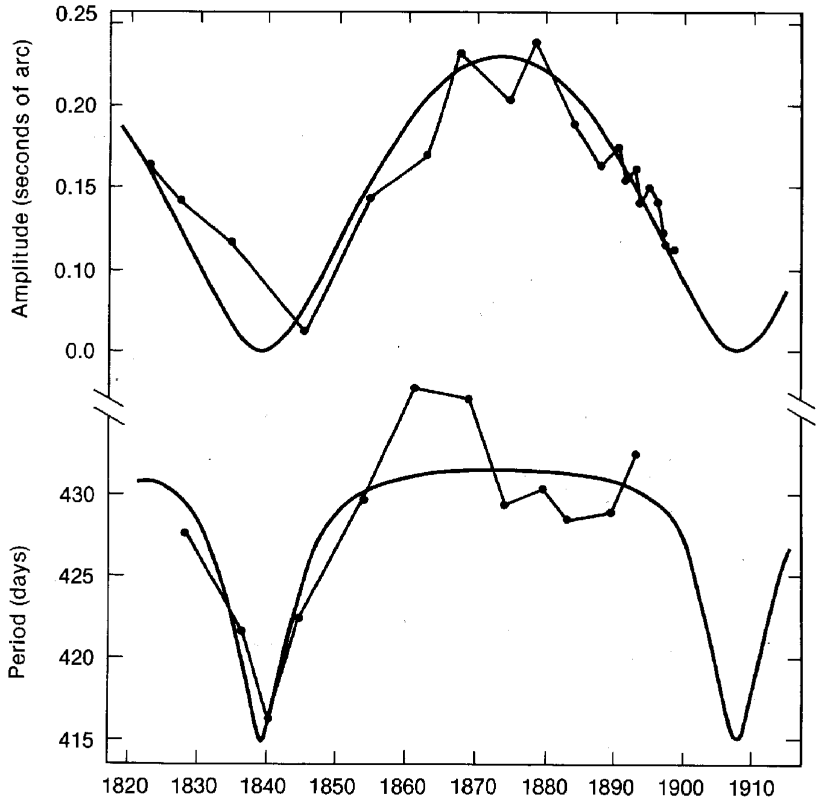

FIGURE 3. Chandler's figure showing the variation in the amplitude and period of the 14-month component of polar motion. The dots connected by straight lines are the observed values, and the smooth lines are the values computed by Chandler using 428- and 436-day components.

diction did not come true in 1910, nor by his death in 1913, and it was soon forgotten by the scientific community. But some fifteen years later, circa 1926, an event just such as Chandler had predicted did occur.

Based on numerical analysis of seventy-eight years of polar motion observations by the International Latitude Service, Dickman (1981) summarizes reports of a large change in the phase and amplitude of the Chandler component during the period from about 1925 to 1940. According to Dickman the behavior of the Chandler motion could not be interpreted to be the result of noise in the data, because that would have caused the phase to vary erratically, rather than in the smooth systematic manner indicated by his analysis. The observed variation in phase could be modeled as a sudden and temporary change in the Chandler frequency of 0.003 cycles per year, equivalent to a period of 418 days, but Dickman preferred to think of the motion as resulting from the beating of two components. Totally independent investigations of two disjoint (in time, instrumentation, and observing locations) polar motion time series could hardly have agreed more closely. Could it be that Chandler's prediction will yet prove to be essentially correct, if somewhat less accurate than one might hope? Ironically, if this phenomenon is periodic, it should next occur circa 2010, precisely one century after Chandler's original prediction.

VARIABLE STARS

Chandler released his first catalogue of 225 variable stars in 1888. As a rigorous observer of variable stars, discoverer of many, and enthusiastic computer of the elements of their variations, he was personally responsible for the elements of 124 of the 160 periodic stars in this, the first of three, full-scale catalogues. The second was published in 1893 and contained 260 stars. The third, in 1896, had 393 stars. Between the publication of each of the full catalogues, Chandler also published several supplements and revisions so that the newest discoveries would be available to the community as soon as possible. This work required that Chandler spend thousands of hours observing and recording his results, a task that he attacked with his usual extraordinary enthusiasm.

The rules governing the nomenclature of variable stars were still inconsistent, so Chandler introduced a blueprint of his own. In his system the designation of a variable star was obtained by dividing the number of seconds in its right ascension for the year 1900 by ten. This scheme insured that the numeration would not be disturbed by the addition of new discoveries. This system was used in all of Chandler's work, but it is not used today.

Chandler's work on cataloging variable stars led him to many new discoveries, including a correlation between their color and the period of their variability. Following clues given by Lalande and Schönfeld (Chandler, 1890), he determined that the Algol-type stars are strikingly white; the very short-period stars range from nearly colorless to yellow; and that those of longer and longer periods show a color of deeper and deeper red. In fact he noted that variable stars with a period of over 400 days consist solely of red stars. Chandler also detected correlations between the periods of the variable stars and the average range of the variations of their brightness. For periods under two months, the maximum brightness could be expected to be about three times the minimum, for periods of four to eight months, maximum brightness was about thirty times the minimum, and for periods longer than eight months maximum brightness was sixty times the minimum. But, perhaps the most important contribution Chandler made to the study of variable stars was his encouragement to other astronomers to participate in the observing program, especially in the southern hemisphere. He wrote a number of papers urging astronomers to enter this useful study, even including detailed observing instructions.

In 1894 Chandler published a paper (Chandler, 1894) contending that the photometric results obtained by Harvard College with their new meridian photometer left "an impression of distrust whether any of these observations are suitable for any precise or critical purpose." It may seem ironic that the man who had such success with his newly invented Almucantar would be such an outspoken critic of the first products of the new meridian photometer. But careful examination of these papers shows that Chandler's criticisms were directed primarily at the apparent lack of care taken in making the observations and the resulting poor reliability of the results obtained, not at the basic design of the instrument. His concerns were justified by the fact that fifteen out of the first eighty-six telescopic variables observed showed serious errors. Always a man to solve puzzles, Chandler was able not only to report these errors, but also to deduce correctly the probable cause for each of them.

Edward Pickering, then director of the Harvard Observatory, was concerned that Chandler's criticisms might weaken support for the photometric research and responded publicly (Jones and Boyd, 1971). Chandler's colleagues, John Ritchie, Jr., and B. A. Gould, entered the dispute on his behalf. For the next several months the debate raged, fueled chiefly by Ritchie, in local newspapers and in the *Astronomische Nachrichten,* where Pickering accused Chandler of personal animosity. In the supplement to his second catalogue, Chandler entered several variables in the southern sky based on examinations of the Harvard College Observatory photographs made at its Boyden Station in Arequipa. He again stated his distrust in the accuracy of the positions and identifications, but relied on the assurances of Pickering that each instance had been confirmed by independent examination. Yet still, he marked those stars with the initials H.C.O. to signify that the observatory in question was the sole authority.

COMPUTATIONAL SKILLS LEAD TO DIVERSE STUDIES

Chandler's exceptional computational skills led him into diverse facets of astronomy. He was known to spend countless hours at his desk working his computations with speed and vigor, often foregoing food and sleep in pursuit of his goal. He computed the orbital elements and generated an ephemeris for any comet for which he could obtain adequate observations. His investigations of the orbit of comet 1889d allowed him to identify it as the previously discovered Lexell's comet (Chandler, 1889). He calculated and recalculated the constant of aberration, publishing sixteen papers on this subject alone. He even used his mathematical skills to speculate on the size of the two newly discovered moons of Mars (Chandler, 1877). His values were too small by about a factor of two because he assumed much too high albedos, but until space probes visited other bodies in the solar system a century later there was little information from which he could obtain better estimates.

In 1898 the minor planet Eros (first called Witt's planet or planet DQ) was discovered. Since Eros' orbit approached Earth more closely than any other minor planet, it could be used to determine more accurately the distance to the sun. The exact orbit of this planetoid needed to be calculated as soon as possible. Chandler wrote to Pickering asking him to launch a search for the planetoid in the Harvard collection of photographic plates. Using Chandler's rough ephemeris, the Scottish astronomer Wilhelmina Fleming was able to recover an image of Eros on a plate from 1893. Chandler was impressed by this "inspired find" and was able to calculate a more exact orbit (Jones and Boyd, 1971). This more exact orbit produced more observations on plates from 1894 and 1896. This cooperation repaired the rift between Pickering and Chandler and friendly relations were restored.

During the search for previously undetected observations of Eros in 1898, Chandler wrote a letter to the editor of *The Observatory* regarding the name of the tiny new planet (Chandler, 1898). He suggested the name "Pluto," the only one of the six surviving children of Saturn that had not yet been assigned to major planets or members of the asteroid belt. Chandler noted that "Pluto under his older name, Hades, was the invisible or unknown, the God of Darkness." Although the name was not used at the time, this suggestion may have influenced the naming of the current planet Pluto after its discovery in 1930.

THE TELEGRAPHIC CODE

One of the many obstacles associated with astronomy that Chandler saw fit to tackle was the important task of telegraphic transmission of scientific data. "In astronomy," Chandler stated, "where accuracy is of vital importance, the details of a message are such that they are of little interest to the ordinary operator, and afford no means of correcting mistakes by the context" (Chandler, 1881). In 1881 he and John Ritchie, Jr., devised a code that could be used to telegraph important data. The code made use of a readily available dictionary, the 1876 edition of *Worcester's Comprehensive Dictionary*. Using this code, no numbers had to be transmitted. All numbers could be represented as words. For example, the number 16,718 was replaced with the 18th word on page 167 (electrize), or April 14d. 10h. 48m. could be represented by the number 134.45 (134.45th day of the year) or the 45th word on page 134 (Crush) and so on. During the first fourteen messages of comet discoveries in the months following the implementation of the code, frequent errors were detected in transmission, but the control words were easily corrected by the receiver. Based on the success of this new system the Smithsonian Institution relinquished control of the Department of International Exchange of Astronomical Information for the United States to the Harvard College Observatory where this important activity continued for more than eighty years (Jones and Boyd, 1971).

IN CONCLUSION

Seth Carlo Chandler, Jr., was a talented, enthusiastic scientist whose career spanned a half century and included many exciting new discoveries in diverse facets of astronomy. But his era was quickly followed by discoveries in science that shone so brightly as to make his achievements pale in comparison. The discoveries of special relativity, general relativity, and quantum mechanics early in the twentieth century completely redefined the understanding of our universe, making many of the discoveries of the nineteenth century seem insignificant. Observatories continued to track the motion of the pole without interruption even during the two world wars, but this activity was considered an operational requirement for treating geodetic and astrometric measurements, with little scientific importance or excitement. The discovery of polar motion was eventually reduced to a brief anecdote in which Chandler was generally described as a wealthy merchant from Boston, an amateur who had just happened upon polar motion. At least one author went so far as to speculate that Chandler probably had little idea of the importance of his discovery.

Ironically, Chandler was very active in the amateur astronomy community of his time. He was, for some time, president of the Amateur Astronomers' Club of Boston. Many of his earlier writings were published in the *Science Observer*, which was directed primarily toward the amateur community and gave detailed directions on how certain observations could be conducted by amateurs. He clearly believed that amateurs could make a strong contribution to the discovery and monitoring of variable stars, one of the primary subjects of interest in his era, and he published detailed descriptions of the observing techniques and special instrumentation he developed. However, Chandler had worked directly with the leading astronomers of his time beginning in high school and did in fact make his living for some years in geodetic astronomy. He knew very well the importance of his findings and published extensively. Fortunately, his contributions have survived and his work has regained much of the recognition it once enjoyed and deserves.

AN EXTENSIVE COLLECTION OF Chandler's private and professional correspondence has been assembled and is available on microfilm from the American Institute of Physics, Center for History of Physics, 335 East 45th Street, New York, New York 10017.

REFERENCES

Carter, W. E. and Seth Carlo Chandler, Jr. Discoveries in polar motion. *EOS* 68(24):593 and 603-5 (1987).

Carter, W. E., and D. S. Robertson. Studying the Earth by very-long-baseline interferometry. *Sci. American* 254:46-54 (1986).

Chandler, S. C. On the diameter of the satellites of Mars. *Science Observer* 1(4):13-14 (1877).

Chandler, S. C. On the telegraphic transmission of astronomical data. *Science Observer* 3(9-10):65-77 (1881).

Chandler, S. C. The almucantar. *Annals of the Astronomical Observatory of Harvard College*. Cambridge, Massachusetts: University Press, John Wilson and Sons (1887):222.

Chandler, S. C. On the action of Jupiter in 1886 upon comet d1889, and the identity of the latter with Lexell's comet of 1770. *Astron. J.* 205:100-103 (1889).

Chandler, S. C. Address before the section of mathematics and astronomy, American Association for the Advancement of Science. *Proceedings of the American Association for the Advancement of Science* 39 (1890).

Chandler, S. C. On the variation of latitude, I. *Astron. J.* 248:59-61 (1891a).

Chandler, S. C. On the variation of latitude, II. *Astron. J.* 249:65-70 (1891b).

Chandler, S. C. On the variation of latitude, V. *Astron. J.* 267:17-22 (1892a).

Chandler, S. C. On the variation of latitude, VI. *Astron. J.* 273:65-72 (1892b).

Chandler, S. C. On the variation of latitude, VII. *Astron. J.* 277:97-101 (1892c).

Chandler, S. C. On the variation of latitude, VIII. *Astron. J.* 307:159-62 (1893).

Chandler, S. C. On the observations of variable stars with the meridian-photometer of the Harvard College Observatory. *Astronomische Nachrichten* 134(3214):355-60 (1894).

Chandler, S. C. The name of planet DQ, To editors of The Observatory. *The Observatory* 21:449-50 (1898).

Chandler, S. C. On a new component of the polar motion. *Astron. J.* 490:79-80 (1901a).

Chandler, S. C. On the new component of the polar motion. *Astron. J.* 494:109-12 (1901b).

Chandler, S. C. Variation of latitude from Molyneux's and Bradley's observations. *Astron. J.* 513:71-75 (1901c).

Comstock, G. C. On the supposed secular variation of latitudes, a reply to Mr. S. C. Chandler. *Astron. J.* 255:116-19 (1892).

Dickman, S. R. Investigation of controversial polar motion features using homogeneous International Latitude Service data. *J. Geophys. Res.* 86:4904-12 (1981).

Gould, B. A. Periodic variation of the latitude at Cordoba. *Astron. J.* 258:137-40 (1892).

James, M. A. *Elites in Conflict.* New Brunswick, New Jersey: Rutgers University Press (1987).

Jones, B. Z., and L. G. Boyd. *The Harvard College Observatory, the First Four Directorships, 1839-1919.* Cambridge, Massachusetts: The Belknap Press of Harvard University Press (1971):495

Küstner, F. Neue method zur bestimmung der aberrations-constante nebst untersuchungen uber die veranderlichkeit der polhohe. *Koniglichen Sternwarte* 3:1 and 46-47 (1888).

Küstner, F. Ueber polhohen-aenderungen beobachtet 1884 bis 1885 zu Berlin und Pulkova. *Astronomische Nachrichten* 2993:273-78 (1890).

Mulholland, J. D. and W. E. Carter. Seth Carlo Chandler and the observational origins of geodynamics. In *High-Precision Earth Rotation and Earth-Moon Dynamics.* Edited by O. Calame. Dordrecht, Holland: D. Reidel Publishing Company (1982):xv-xix.

Newcomb, S. On the periodic variation of latitude, and the observations with the Washington prime-vertical transit. *Astron. J.* 251:81-83 (1891).

Newcomb, S. Remarks on Mr. Chandler's law of variation of terrestrial latitudes. *Astron. J.* 271:49-50 (1892).

Markowitz, W. Polar motion: history and recent results. *Sky and Telescope* 52:99-108 (1976).

SELECTED BIBLIOGRAPHY

1877

On the diameter of the satellites of Mars. *Science Observer* 1(4):13-14.

On the element of R Aquarii. *Science Observer* 1(5):21-22.

On the methods of observing variable stars I. *Science Observer* 1(7):42-43.

On the methods of observing variable stars II, *Science Observer* 1(8):50-52.

1878

On the methods of observing variable stars III. *Science Observer* 1(9):57-59.

On the methods of observing variable stars IV. *Science Observer* 1(10):66-68.

On the relationship between the colors and periods of variable stars. *Science Observer* 2(1):1-2.

A new method of finding the time without instruments. *Science Observer* 2(2):13-15.

1879

Elements and ephemeris of Comet 1879, I. (Swift). *Science Observer* 2(9):65-66.

Improved elements and ephemeris of Comet I, 1879. *Science Observer* 2(10):77-78.

Elements and ephemeris of Palisa's Comet. *Science Observer* 2(11):81.

Variable stars. *Science Observer* 2(12):95-96.

1880

A break-circuit device for box chronometers. *Science Observer* 3(1):1.

The chronodeik. *Science Observer* 3(3):17-23.

Elements and ephemeris of Swift's Comet. *Science Observer* 3(4):28-29.

The almucantar (a new instrument for the determination of time and latitude). *Science Observer* 3(5):33-36.

On the probable period of Swift's Comet. *Science Observer* 3(5):37-38.

Swift's Comet (e) 1880 and its identity with Comet III 1869. *Astronomische Nachrichten* 93(2349):327-30.

1881

Comet Pechule, 1880. *Science Observer* 3(6):45-46.

Prof. Pickering, on the variable stars of short period. *Science Observer* 3(7):54-55.

On the telegraphic transmission of astronomical data. *Science Observer* 3(9-10):65-77.

Elliptic elements of Comet (f), 1881-Denning. *Science Observer* 3(11):91.

On a new variable star in the constellation Cetus. *Science Observer* 3(12):105-6.

Elemente des Cometen b 1881. *Astronomische Nachrichten* 100(2384):121

Elemente und ephemeride des Cometen e 1881. *Astronomische Nachrichten* 100(2396):320.

On the periodicity of Comet (Denning) 1881 V. *Astronomische Nachrichten* 101(2406):93.

1882

Sawyer's variable. *Science Observer* 4(1-2):11.

On some suspected variable stars. *Science Observer* 4(7-8):60-62.

Notes on some recently discovered variable stars. *Science Observer* 4(11):88.

On the variability of DM. +23 1599. *Astronomische Nachrichten* 102(2433):139.

On the period of R Hydrae. *Astronomische Nachrichten* 103(2463):225-34.

1883

Elemente des Cometen 1883 Brooks-Swift. *Astronomische Nachrichten* 105(2504):127.

On the variability of 36 (Uran. Argentina) Ceti. *Astronomische Nachrichten* 105(2517):333-36.

On the outburst in the light of the Comet Pons-Brooks Sept 21-23. *Astronomische Nachrichten* 107(2553):131.

On the possible connection of the Comet Pons-Brooks with a meteor stream. *Astronomische Nachrichten* 107(2561):275.

Results of tests with the "almucantar" in time and latitude. *The Sidereal Messenger* 2(9):269-74.

1884

Elemente und ephemeride des Cometen 1884 II. *Astronomische Nachrichten* 109(2606):223.

Elements of Comet 1884 Wolf. *Astronomische Nachrichten* 110(2625):143.

On a convenient formula for differential refraction in ring-micrometer observations. *Astronomische Nachrichten* 110(2628):177-80.

1885

Dr. Gould's star in sculptor. *Astronomische Nachrichten* 111(2661):333.

On the latitude of Harvard College Observatory. *Astronomische Nachrichten* 112(2672):113-20.

On the right ascensions of certain fundamental stars. *Astronomische Nachrichten* 112(2687):381-88.

Berichtigung zu on the right ascensions of certain fundamental stars in nr. 2687. *Astronomische Nachrichten* 113(2690):17.

1886

On the light-variations of Sawyer's variable in Vulpecula. *Astronomical Journal* 7(145):1-3.

Elements and ephemeris of the Comet 1886 f (Barnard, Oct. 4). *Astronomical Journal* 7(147):23.

Elements and ephemeris of the Comet 1886 f (Barnard, Oct. 4) (continued from number 147). *Astronomical Journal* 7(148):30.

On a new short-period variable in Cygnus. *Astronomical Journal* 7(148):32.

On a new variable of the Algol type. *Astronomical Journal* 7(149):40.

On the new Algol-variable in Cygnus. *Astronomical Journal* 7(150):47-48.

On the light-ratio unit of stellar magnitudes. *Astronomische Nachrichten* 115(2746):145-54.

On the variable 10 Sagittae 19h49m25 + 16 15'4 (1855). *Astronomische Nachrichten* 115(2749):217-20.

1887

Note on an inaccuracy in the development of a differential refraction formula. *Astronomical Journal* 7(151):53.

Notes on some places of Auwer's fundamental catalogue. *Astronomical Journal* 7(155):81-83.

On the orbit of the Great Southern Comet 1887 a. *Astronomical Journal* 7(156):92-95.

On the orbit of the Great Southern Comet 1887 a. *Astronomical Journal* 7(157):100.

Elements and ephemeris of Comet 1887 e (Barnard, May 12). *Astronomical Journal* 7(157):104.

Improved elements and ephemeris of Comet 1887 e. *Astronomical Journal* 7(160):121-22.

Investigation of the light-variations of U Ophiuchi. *Astronomical Journal* 7(161):129-33.

Investigation of the light-variations of U Ophiuchi. *Astronomical Journal* 7(162):137-40.

Ephemeris for minima of the two new Algol-variables. *Astronomical Journal* 7(162):144.

On the two new Algol-type variables Y Cygni and R Canis Majoris. *Astronomical Journal* 7(163):150-51.

Ring-micrometer observations of Comet e 1887. *Astronomical Journal* 7(163):152.

Observations of X Cygni. *Astronomical Journal* 7(164):159-60.

The almucantar. In: *Annals of the Astronomical Observatory of Harvard College*, vol. 17. (Cambridge, Massachusetts: University Press, John Wilson and Sons):222.

1888

On the period of Algol. *Astronomical Journal* 7(165):165-68.

On the period of Algol (continued). *Astronomical Journal* 7(166):169-75.

On the period of Algol (continued). *Astronomical Journal* 7(167):177-83.

On the observation of the variables of the Algol-type. *Astronomical Journal* 7(168):187-89.

On a new variable of long period. *Astronomical Journal* 8(171):24.

Ephemeris of variables of the Algol-type. *Astronomical Journal* 8(173):40.

Ephemeris of variables of the Algol-type. *Astronomical Journal* 8(182):107-8.

Ephemeris of variables of the Algol-type. *Astronomical Journal* 8(188):159.

Catalogue of variable stars. *Astronomical Journal* 8(179-80):81-92.

On the observation of the Fainter Minima of the telescopic variables. *Astronomical Journal* 8(183):114-17.

On some remarkable anomalies in the period of Y Cigni. *Astronomical Journal* 8(185):130-32.

On the square bar micrometer. *Memoirs of the American Academy of Arts and Sciences,* Vol. XI. Cambridge: University Press, John Wilson and Sons.

On the colors of the variable stars. *Astronomical Journal* 8(186):137-40.

1889

Note on the equation of the meridian transit instrument. *Astronomical Journal* 8(187):147.

Contributions to the knowledge of the inequalities in the periods of the variable stars. *Astronomical Journal* 8(189):161-66.

Contributions to the knowledge of the inequalities in the periods of the variable stars. *Astronomical Journal* 8(190):172-75.

On the general relations of variable star phenomena. *Astronomical Journal* 9(193):1-5.

On the light-variations of U Cephei. *Astronomical Journal* 9(199):49-53.

Note on the variable Y Cigni. *Astronomical Journal* 9(204):92-93.

On the period of U Coranae. *Astronomical Journal* 9(205):97-99.

On the action of Jupiter in 1886 upon Comet d 1889 and the identity of the latter with Lexell's Comet of 1770. *Astronomical Journal* 9(205):100-103.

Elements of Comet 1889 (Brooks, July 6). *Astronomische Nachrichten* 123(2935):111.

1890

Contributions to the knowledge of the inequalities in the periods of the variable stars. *Astronomical Journal* 9(208):126.

Supplement to first edition of the catalogue of variable stars. *Astronomical Journal* 9(216):185-87.

Elements of Paul's Algol-type variable, S Antliae. *Astronomical Journal* 9(216):190-91.

Ephemeris of S Antliae. *Astronomical Journal* 10:10.

Contributions to the knowledge of the inequalities in the period of the variable stars. *Astronomical Journal* 10(229):103.

On the present aspect of the problems concerning Lexell's Comet. *Astronomical Journal* 10(231):118-20.

On Jupiter's perturbation of Comet 1889 V in 1922. *Astronomical Journal* 10(232):124-25.

On the period of 2100 U Orionis. *Astronomical Journal* 10(233):133.
Address before the Section of Mathematics and Astronomy, Indianapolis meeting, American Association for the Advancement of Science, August 1890. *Proceedings of the American Association for the Advancement of Science,* vol. 39.

1891

Definitive orbits of the companions of Comet 1889 V. *Astronomical Journal* 10(236):153-59.
Definitive orbits of the companions of Comet 1889 V. *Astronomical Journal* 10(237):161-63.
On the orbit of Comet 1887 IV. *Astronomical Journal* 10(237):166-67.
On the rigorous computation of differential refraction. *Astronomical Journal* 10(239):181-82.
Contributions to the knowledge of the inequalities in the periods of the variable stars. *Astronomical Journal* 11(242):14-15.
On the variation of latitude, I. *Astronomical Journal* 11(248):59-61.
On the variation of latitude, II. *Astronomical Journal* 11(249):63-70.
On the variation of latitude, III. *Astronomical Journal* 11(250):75-79.
On the variation of latitude, IV. *Astronomical Journal* 11(251):83-86.

1892

On the supposed secular variation of latitudes. *Astronomical Journal* 11(254):107-9.
Contributions to the knowledge of the variable stars. *Astronomical Journal* 11(255):113-16.
Contributions to the knowledge of the variable stars. *Astronomical Journal* 11(256):121-26.
Note on secular variation of latitude. *Astronomical Journal* 11(257):134-35.
On the Washington prime-vertical observations. *Astronomical Journal* 11(262):174-75.
On the variation of latitude, V. *Astronomical Journal* 12(267):17-22.
On the variation of latitude, VI. *Astronomical Journal* 12(272):57-62.
On the variation of latitude, VI (continued). *Astronomical Journal* 12(273):65-72.
On the variation of latitude, VII. *Astronomical Journal* 12(277):97-101.

A device for eliminating refraction in micrometric or photographic measures. *Astronomical Journal* 12(271):51-52.

Sweeping ephemeris for bodies moving in the Biela-orbit. *Astronomical Journal* 12(281):133-34.

1893

On the influence of latitude-variations upon astronomical constants and measurements. *Astronomical Journal* 12(284):153-55.

On the constant of aberration. *Astronomical Journal* 12(287):177-79.

On the nomenclature of recently discovered variables. *Astronomical Journal* 13(290):12-13.

On the constant of aberration, II. *Astronomical Journal* 13(293):33-36.

Contributions to the knowledge of the variable stars VII. *Astronomical Journal* 12(294):45-47.

On the constant of aberration, III. *Astronomical Journal* 13(296):57-61.

Systematic correction of the declinations of the fundamental catalog for variations of latitude. *Astronomical Journal* 12(296):63-64.

On the constant of aberration, IV. *Astronomical Journal* 13(297):65-70.

On the constant of aberration, V. *Astronomical Journal* 13(298):76-79.

Second catalog of variable stars. *Astronomical Journal* 13(300):89-110.

On the variation of latitude, VIII. *Astronomical Journal* 13(307):159-62.

Ephemerides of long-period variables for 1894. *Astronomical Journal* 13(308):172-73.

On the nomenclature of recently discovered variables. *Astronomische Nachrichten* 132(3161):283-86.

1894

On the observations of variable stars with the meridian-photometer of the Harvard College Observatory. *Astronomische Nachrichten* 134(3214):355-60.

On the Harvard photometric observations. *Astronomische Nachrichten* 136(3246):85-90.

Schreiben von Herrn S. C. Chandler an Prof. H. Kreutz Betr. Z Herculis. *Astronomische Nachrichten* 136(3260):331-33.

On Pond's double-altitude observations, 1825-35. *Astronomical Journal* 14(313):1-6.

Note on Nyren's vertical-circle observations, 1882-91. *Astronomical Journal* 14(314):13-14.

On Pond's double-altitude observations, 1825-1835. *Astronomical Journal* 14(315):17-20.

Supplement to second catalogue of variable stars. *Astronomical Journal* 14(319):51-53.

Variation of latitude from the Greenwich mural-circle observations, 1836-51. *Astronomical Journal* 14(320):57-60.

On the inequalities in the coefficients of the law of latitude-variation. *Astronomical Journal* 14(322):73-75.

On some further characteristics of the polar rotation. *Astronomical Journal* 14(323):82-84.

Ephemerides of long-period variables for 1895. *Astronomical Journal* 14(327):118-19.

On a new variable of the Algol-type, 6442 Z Herculis. *Astronomical Journal* 14(328):125

Further proof of eccentricity in the annual component of the polar motion. *Astronomical Journal* 14(329):129-32.

On a new variable of short period. *Astronomical Journal* 14(329):135.

Elements of the polar motion from all published observations from 1889.0-1894.5. *Astronomical Journal* 14(330):141-43.

The variation of terrestrial latitudes. *Publications of the Astronomical Society of the Pacific* 6:180-82.

1895

On the parallax of B Cassiopeae. *Astronomical Journal* 14(333):163.

Orbit of Comet e 1894. *Astronomical Journal* 14(333):167-68.

Note on the investigations of Gonnessiat upon the variations of latitude observed at Lyons. *Astronomical Journal* 14(334):174.

Improved elements of Comet e 1894 IV. *Astronomical Journal* 15(338):10.

On Comet e 1894 and its identity with DeVico's (1814 I). *Astronomical Journal* 15(338):13-15.

On the annual term of the latitude-variation from the Lyons observations. *Astronomical Journal* 15(344):60-61.

Revised supplement to second catalogue of variable stars. *Astronomical Journal* 15(347):81-85.

The latitude-variation tide. *Astronomical Journal* 15(351):127-28.

On a new variable of peculiar character, 8598 U Pegasi. *Astronomical Journal* 15(358):181.

Assignment of notation for recently discovered variables. *Astronomical Journal* 15(358):184.

Tables of the trajectory of the pole, for computing variations of latitude. *Astronomical Journal* 15(360):193-96.

On a new determination of the constant of nutation. *Astronomical Journal* 16(361):1-6.

1896

On standard systems of declination and proper motion. *Astronomical Journal* 16(364):28-29.

Elements and ephemeris of Comet a 1896. *Astronomical Journal* 16:56-72.

Notation of recently discovered variables. *Astronomical Journal* 16(369):71-72.

Elements of variation of 8598 U Pegasi. *Astronomical Journal* 16(374):107-8.

Third catalogue of variable stars. *Astronomical Journal* 16(379):145-72.

On the companions of the periodic Comet 1889 V. *Astronomical Journal* 17(385):1.

Corrected ephemeris of the component C of the periodic Comet 1889 V. *Astronomical Journal* 17(386):14.

Ephemeris of long-period variables for 1897. *Astronomical Journal* 17(387):17-20.

1897

Trajectory of the pole, for computing latitude-variations in 1897. *Astronomical Journal* 17(392):63.

Notation of recently discovered variables. *Astronomical Journal* 17(392):64

Revised elements of 320 U Cephei. *Astronomical Journal* 17(396):94.

On Nyren's vertical-circle observations, 1882-91. *Astronomical Journal* 17(400):125-27.

Revised elements of 5190 R Camelopardalis. *Astronomical Journal* 17(400):128.

Elements of the annual component of the polar motion from recent observations. *Astronomical Journal* 17(402):141-42.

Correction of the 336 Pulkowa Hauptsterne for latitude-variation. *Astronomical Journal* 17(402):143.

Synthetical statement of the theory of the polar motion. *Astronomical Journal* 17(406):172-75.

On the proposed unification of astronomical constants. *Astronomical Journal* 18(410):15-16.

Note by the editor. *Astronomical Journal* 18(415):54.

1898

Ephemeris of long-period variables for 1898. *Astronomical Journal* 18(420):94-96.

Elements and ephemeris of Comet a 1898. *Astronomical Journal* 18(424):127.

Nature of the variation of U Pegasi. *Astronomical Journal* 18(426):140-41.

Trajectory of the pole for computing latitude-variations in 1898. *Astronomical Journal* 18(426):144.

The aberration-constant of the French conference. *Astronomical Journal* 18(427):149-52.

Note by the editor. *Astronomical Journal* 18(429):165.

Additional correction to Newcomb's aberration from Küstner's observations. *Astronomical Journal* 18(430):179.

Determination of the aberration-constant from right-ascensions. *Astronomical Journal* 19(444):89-92.

Comparison of the observed and predicted motions of the pole, 1890-1898, and determination of revised elements. *Astronomical Journal* 19(446):105-10.

Elements and ephemeris of small planet DQ. *Astronomical Journal* 19(450):148.

Elements and ephemeris of small planet DQ. *Astronomical Journal* 19(451):155.

The small planet DQ at the opposition of 1893-4 and 1896. *Astronomical Journal* 19(452):160-62.

The areal velocities in the annual component of the polar motion. *Astronomical Journal* 19(452):163-64.

1899

Aberration-constant from right-ascension observations. *Astronomical Journal* 20(462):46.

1901

Changes in the annual elliptical component of the polar motion. *Astronomical Journal* 21(489):65-71.

On a new component of the polar motion. *Astronomical Journal* 21(490):79-80.

On the assignment of the nomenclature and the formation of a new catalogue of variable stars. *Astronomical Journal* 21(492):96.

On a new component of the polar motion. *Astronomical Journal* 21(494):109-12.

Definitive formulas for computing variations of latitude. *Astronomical Journal* 21(495):119.

The period of Algol. *Astronomical Journal* 22(509):39-42.

The Greenwich reflex zenith-tube. *Astronomical Journal* 22(511):57-60.

The observations of Algol by Argelander, Schmidt, and Schonfeld. *Astronomical Journal* 22(511):60.

Variation of latitude from Molyneux's and Bradley's observations. *Astronomical Journal* 22(513):71-75.

1902

Variation of latitude from Bessel's and Struve's observations. *Astronomical Journal* 22(515):89-91.

Aberration-constant from Pond's observations, 1825-36. *Astronomical Journal* 22(515):91-92.

The constant of aberration from the San Francisco and Waikiki observations of 1891-92. *Astronomical Journal* 22(517):105-6.

The aberration-constant from Davidson's San Francisco and Waikiki observations. *Astronomical Journal* 22(519):124.

Aberration-constant from Kasan, Prague, Potsdam and San Francisco observations. *Astronomical Journal* 22(520):128-31.

Aberration-constant from Pond's observations of Polaris 1812-19. *Astronomical Journal* 22(520):131-33.

New study of the polar motion for the interval 1890-1901. *Astronomical Journal* 22(522):145-48.

On the possible existence of still another term of the polar motion. *Astronomical Journal* 22(523):154.

Note on Kimura's suggestions in A. J., 517. *Astronomical Journal* 22(524):164.

The probable value of the constant of aberration. *Publications of the Astronomical and Astrophysical Society of America* 1:192.

1903

The probable value of the constant of aberration. *Astronomical Journal* 23(529):1-5.

Questions relating to stellar parallax aberration and Kimura's phenomenon. *Astronomical Journal* 23(530):12-15.

Period of 320 U Cephei. *Astronomical Journal* 23(552):227-28.

1904

Revision of elements of third catalogue of variable stars. *Astronomical Journal* 24(553):1-7.

Elements of 6189 U Ophiuchi. *Astronomical Journal* 24(559):63-64.

Elements of 2610 R Canis Majoris. *Astronomical Journal* 24(559):64.

Ephemerides of long-period variables 1903-1910. *Astronomical Journal* 24(560):65-73.