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JAMES EDWARD KEELER.

By W. W. CAMPBELL.

IT is a painful duty to record the death of Professor Keeler, on August 12, in the forty-third year of his life. The announcement came as a great shock to colleagues and friends widespread, who had seen before him a career of rarest promise. A feeling of grievous loss is borne upon us. As an investigator in astrophysics, there was no one more successful. As a director, there were none more ideal. As a companion, who was more delightful? His premature death involves a loss to astronomy and to the Lick Observatory which is incalculable.

James Edward Keeler was born in La Salle, Illinois, on September 10, 1857, of a long line of New England ancestry. The family removed to Mayport, Florida, in 1869, where Keeler prepared, by private study, for entering college. Here he acquired his fondness for astronomical observation. He established "The Mayport Astronomical Observatory" in 1875–1877. It included a quadrant, with which he observed the altitude of *Polaris* in 1875; a two-inch achromatic telescope, which he first directed to the planets and the nebulæ in December 1875; a clock, and a meridian circle, which he himself constructed and

mounted in 1877. [Keeler's original sketch of the meridian circle, and his written description of it, will be published in the *Publications of the Astronomical Society of the Pacific*.]

Keeler's "Record of Observations made at the Mayport Observatory" contains beautiful colored drawings of Jupiter, Saturn, Venus, and Mars, of double stars, and of portions of the Moon, in addition to data of a numerical character. These early sketches are worthy forerunners of his well-known drawings of many of the same objects in later years.

Mr. Keeler entered Johns Hopkins University late in the year 1877; and, following major courses in physics and German, he was graduated with the degree of A.B. in 1881.

Evidences of the high esteem in which Keeler was held by his instructors are not lacking. He largely defrayed his expenses in college by acting as assistant to some of the lecturers in the experimental courses. His private journal modestly relates the details of an evening lecture on electricity, delivered by him to a circle of young people, in President Gilman's residence. At the end of his freshman year, he accompanied Professor Hastings, as a member of Professor Holden's party from the Naval Observatory, to observe the total solar eclipse of July 29, 1878, at Central City, Colorado. His part was the modest one of making a drawing of the corona. The preliminary practice for this work, the precautions taken, and the conveniences provided, are described in his report, which is a model of scientific writing. In the spring of 1881, Professor Langley requested the Johns Hopkins University to recommend a suitable man for the position of assistant in the Allegheny Observatory. Keeler was named for and accepted the appointment, beginning work several weeks before receiving his degree. In June 1900, one of the physicists who had recommended Keeler for the Allegheny position was speaking to me of this very appointment and said: "I told Professor Langley that one of my strongest reasons for the recommendation is that Keeler doesn't claim to know everything." To the end of his life this charming trait remained unimpaired.

Professor Langley made his noted expedition to the summit of Mount Whitney, California, in the summer of 1881, to determine the value of the "Solar Constant." Mr. Keeler accompanied the expedition in the capacity of assistant, and carried out his share of the program with skill and efficiency. His work at Allegheny during the next two years was closely related to the problems arising from this expedition.

The year 1883–4 was devoted to study and travel in Europe. During the summer semester he attended lectures by Quincke, Bunsen, and Fuchs at Heidelberg. During the winter semester, in Berlin, he heard the lectures on physics by Helmholtz and Kayser, on differential equations by Runge, and on quaternions by Glan. In the Berlin physical laboratory he investigated the "Absorption of Radiant Heat by Carbon Dioxide," a problem suggested, no doubt, by his Mount Whitney experiences.

From June 1884, to April 1886, Mr. Keeler again served as assistant in the Allegheny Observatory. He afforded most efficient help to Professor Langley in his well-known researches on the lunar heat and on the infra-red portion of the solar spectrum.

Early in 1886, Mr. Keeler was appointed assistant to the Lick Trustees. He reached Mount Hamilton on April 25, and at once proceeded to establish the time service. The telegraph line to San Jose was perfected, the transit instrument, the clocks, and the sending and receiving apparatus were installed. The daily time signals were sent over the lines of the Southern Pacific Railway Company on and after January 1, 1887, north to Portland, east to Ogden, and south to El Paso. He remained in personal charge of this service until June 1891.

When the Observatory was completed and transferred to the Regents of the University of California, on June 1, 1888, Mr. Keeler was appointed to the position of Astronomer, and placed in charge of the spectroscopic work. The large spectroscope constructed for the Observatory, mainly from his designs, is an extremely efficient and convenient instrument; for visual observations it has no superior. This instrument was used with great

success in many kinds of spectroscopic work. He confirmed Vogel's observations as to the absence of telluric absorption in the spectrum of Saturn's rings. His observations of the spectrum of Uranus confirmed and extended the results obtained by Huggins and Vogel. He secured a long series of observations of the bright and dark lines in the spectra of γ *Cassiopeiae* and β *Lyrae*. He made an accurate determination of the color curve of the 36-inch objective, which is of very frequent use. His beautiful observations of the spectra of the Orion nebula and thirteen planetary nebulae mark a distinct epoch in visual spectroscopy; and his classical memoir[1] on the subject should be familiar to all spectroscopic observers. In these observations a Rowland plane-grating, 14,438 lines to the inch, was employed, in connection with the 36-inch telescope. The wave-lengths of the bright nebular lines were measured in the third and fourth order spectra—taking advantage of the fact that, other things being equal, high dispersion does not weaken the brightness of a monochromatic bright line. The wave-lengths of the principal nebular line in the fourteen nebulæ were found to vary from 5007.86 t. m. in *N. G. C.* 6790 to 5005.97 t. m. in *G. C.* 4373, with an average probable error for each object of only 0.04 t. m. The discrepancies were attributed to differences in the relative velocities of the nebulæ with reference to the solar system. The velocities themselves could not be determined directly, since the normal wave-length of the principal line was unknown, and there was no known method of reproducing this line artificially. Fortunately, the third line, hydrogen β, was bright enough in the *Orion* nebula to be compared directly with terrestrial hydrogen. The mean result of thirteen sets of such comparisons gave, for the velocity of the nebula, a recession from the solar system of 17.7 ± 1.3 kilometers per second. Correcting the observed wave-lengths of the principal line by the corresponding displacement, its normal wave-length was found to be λ 5007.05 t. m. A comparison of the observed wave-lengths of the line in the thirteen planetary nebulæ with

[1] *Publications of the Lick Observatory*, 3, 161–231.

the normal wave-length gave their velocities with reference to our system. Their values lay between −65 and + 48 kilometers. The average probable error of the velocity obtained for each nebula, depending on all the measures, was only ± 3.2 kilometers per second. The important fact was established that the velocities of the nebulæ are of the same order of magnitude as the velocities of the stars.

In a similar manner the normal wave-length of the second nebular line was found to be λ 4959.02.

Among the first objects observed with the 36-inch telescope were the planetary nebulæ and their stellar nuclei. The observers noticed that the focal length for a nebula is about 0.4 inch longer than for its stellar nucleus: a discrepancy which Professor Keeler at once explained by recalling that the star's light is yellow, whereas that of the nebula is greenish-blue. This appears to be the first recognition of the fact that a great refracting telescope is also a powerful spectroscope, for certain classes of objects, by virtue of the chromatic aberration of its objective [*Mon. Not. R. A. S.*, for 1888, p. 389; *Astr. Nach.* No. 3111].

Professor Keeler's faithful and artistic drawings of Jupiter, made in 1888–1890, with the assistance of the 36-inch equatorial, have no equals.

Professor Keeler resigned from the Lick Observatory staff on June 1, 1891, to succeed Professor Langley as Director of the Allegheny Observatory and Professor of Astrophysics in the Western University of Pennsylvania. His investigations there fully maintained the splendid reputation established for the Observatory by his predecessor. He comprehended the possibilities and limitations of his situation, and adapted himself to them. His spectroscopic researches were largely confined to the orange, yellow, and green regions of the spectrum, since they would be less strongly affected by the smoky sky for which that vicinity is famous.

The Allegheny spectroscope, constructed from his designs in 1891–2, contains a number of valuable improvements. The

ease with which it may be converted from a three-prism to a one-prism, or to a grating spectroscope, commends the plan to all. The use of three simple prisms is a departure which has been followed with advantage in many later instruments.

We may mention three noteworthy series of observations made with this instrument.

An extensive investigation of the Orion nebula and the stars immersed in it established the fact that nearly all the bright lines in the nebular spectrum have corresponding dark lines in the stellar spectra, and thus that the nebula and stars are closely related.[1]

Keeler's observations of the spectrum of Saturn's rings are of extraordinary interest. Considering the means at hand, they have never been surpassed in excellence or beauty. The classic researches of Clerk Maxwell on the composition of the rings, leading to the conclusion that they must be a cluster of little moons revolving in circular orbits, found their worthy counterpart in Keeler's spectrographic proof that every point in the ring system is moving with the velocity which a moon would have if situated at that distance from the planet. Let us not forget that these observations were made with a 13-inch telescope, in a smoky sky, which restricted the photographs to the low dispersion of the green region of the spectrum.

Professor Keeler's main piece of work at Allegheny, on the spectra of Secchi's third type stars, remains unpublished, but the measures and reductions are left in an advanced stage.

Professor Keeler was appointed to the position of Director of the Lick Observatory on March 8, 1898. He entered upon his new duties on June 1, 1898.

Without making any rearrangement of the work of the existing staff, but giving every encouragement to continue along the same lines, Professor Keeler arranged to devote his own observing time to the Crossley reflector. The story of the wonderful success with this difficult instrument is familiar to all the readers

[1] Simultaneous observations of the same objects at another observatory led to the same conclusion.

of the ASTROPHYSICAL JOURNAL. He was quick to recognize that this instrument was not in condition to produce satisfactory results. He proceeded energetically to make one change after another, and to overcome one difficulty after another, until at the end of five months he was ready to submit it to trial. On November 14, he secured a splendid negative of the Pleiades, and on the 16th a superb negative of the Orion nebula. Having satisfied himself of the enormous power of the reflector in nebular photography, he entered upon the program of photographing the brighter Herschel nebulæ. More than half of the subjects on his program have been satisfactorily photographed. The Observatory possesses a set of negatives of the principal nebulæ which is priceless, and unequaled.

These photographs record, incidentally, great numbers of new nebulæ. A conservative estimate places the number within reach of the Crossley reflector at 120,000.

It had previously been supposed that the great majority of nebulæ were irregular in form, and that only a few were spirals. These photographs have recorded more spiral nebulæ than irregular ones. This discovery bears profoundly upon the theory of the cosmogony, and must be considered as of the first order.

It is time to speak of Professor Keeler's work as Director. I but faintly reflect the views of every member of the staff, and, indeed, of all who have been interested in the work of the Lick Observatory, when I say that his administration was completely successful. He cherished and promoted ideal conditions in this ideal place. He made a success of his own work, in a splendidly scientific manner; and he saw to it that everyone had every possible opportunity to do the same. No member of the staff was asked to sacrifice his individuality in the slightest degree. Nor were demands made for immediate results. The peace of mind of the investigator, so absolutely required for complete success, was full and undisturbed. Withal, Professor Keeler's administration was so kind and so gentle—and yet so effective—that the reins of government were seldom seen and never felt.

The elements of his successes are simple, and plainly in view. His openness and honesty of character, his willingness and quickness to see the other man's point of view, his strong appreciation of the humorous, as well as the serious, and, above all, his abounding good sense—these traits made his companionship delightful and charming.

Scientifically, Professor Keeler never groped aimlessly in the dark. He would not attack a problem until he had as fully as possible comprehended its nature, and the requirements for success. With the plan of attack completely considered, the execution of his plans usually involved little loss of time. The Crossley reflector has afforded a case in point. It was seldom necessary for him to repeat any part of his work.

His published papers have a completeness, a ripeness, and a finish rarely seen. A complete list of his published writings is appended.

The honorary degree of Sc.D. was conferred upon Professor Keeler in 1893 by the University of California. The Rumford Medal was bestowed upon him in 1898 by the American Academy of Arts and Sciences, and the Henry Draper Medal in 1899 by the National Academy of Sciences. He was a member of the National Academy of Sciences; an Associate of the American Academy of Arts and Sciences; a Fellow and Foreign Associate of the Royal Astronomical Society; a Fellow of the American Association for the Advancement of Science; a member and officer of the Astronomical and Astrophysical Society of America; an honorary member of the Toronto Astronomical and Physical Society; the president of the Astronomical Society of the Pacific; a member of the Washington Academy of Sciences; and various other organizations. He was an associate editor of *Astronomy and Astro-Physics* during 1893 and 1894, and editor (with Professor George E. Hale) of the ASTROPHYSICAL JOURNAL from 1895 to the time of his death.

It appears that he had been a mild sufferer from heart weakness for many years. It is feared that on Mt. Hamilton he worked beyond his strength. His weakness seems to have

developed rapidly this year: a cold contracted in June he could not throw off. He left the Observatory on July 30, with no anxiety, to secure medical treatment in San Jose, and to spend a prospective vacation in northern California. Increasing difficulty in breathing led him to seek skilled assistance in San Francisco, on August 10. The dangerous condition of his heart was realized on the next day; and on the twelfth a stroke of apoplexy proved fatal.

It is known that Professor Keeler had planned his work with the Crossley Reflector far into the future. It is sad to relate that a small spectrograph, which he was most anxious to employ on certain interesting objects, was completed on the day of his leaving the Observatory. Arrangements have been made for carrying out his program.

The absence of one so old in experience and so ripe in judgment will be most seriously felt at the Lick Observatory, and throughout the profession.

Professor Keeler married Miss Cora S. Matthews, at Oakley Plantation, Louisiana, on June 16, 1891. Of her great sorrow, and of the grievous loss to the two children, it would be futile to speak. Their departure leaves the mountain inexpressibly sad.

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