SCIENCE

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JAMES EDWARD KEELER.

THE sudden death of Professor James E. Keeler, Director of the Lick Observatory, which occurred at San Francisco on August 12th, removes one who stood at the very forefront of astrophysical research. The advanced position occupied by the United States in the development of astrophysics is due as much to Keeler as to any other individual. The high quality of his own investigations, and the effect of his example on the work of others, have been factors of the first importance in building up the physical side of astronomy in this country. The shock caused by his wholly unexpected death has been felt by many, not least by some of those whose friendship for him grew out of a common interest in his own field of science.

As he was still in his forty-third year, and had until recently enjoyed the best of health, there seemed to be every reason to expect that his important contributions to astrophysical literature would continue for many years to come. But a severe cold, contracted in the course of his recent work with the Crossley reflector, developed into pneumonia, which was complicated with heart trouble. From the accounts which have so far reached us it appears that he withstood this first illness, and had just entered a hospital in San Francisco, when he was seized with an apoplectic stroke from which he did not rally.

James Edward Keeler was born at La Salle, Illinois, on September 8, 1857. As a boy he was greatly interested in science, and I have often heard him speak of his early chemical experiments and astronom-

ical observations made with instruments of his own construction. His father, who was a paymaster in the navy, served with distinction in the civil war, and was on board the *Monitor* during her memorable fight with the *Merrimac*. Keeler's qualifications for scientific work clearly showed themselves at the Johns Hopkins University, where he took an undergraduate course, and served as assistant to Professor Hastings, with whom he observed the total solar eclipse of 1878 in Colorado. His report on the eclipse, which is accompanied by a drawing of the corona, is a characteristically clear and concise paper.

Shortly after this he was appointed assistant at the Allegheny Observatory, where he had an important part in the long series of bolometric investigations carried on by Professor Langley, then Director of the Observatory. In July, 1881, he was a member of Professor Langley's well-known expedition to Mount Whitney, in Southern California, where an extensive region in the extreme infra-red of the solar spectrum was discovered with the bolometer.* Later he studied for two years in Berlin and Heidelberg under Helmholtz and Quincke, and returned to the Allegheny Observatory, where he remained until appointed a member of the staff of the Lick Observatory. His work on Mt. Hamilton commenced in 1886, and for some time he was the only astronomer at the Observatory, which was still in process of construction. In May, 1891, he was elected Professor of Astrophysics in the Western University of Pennsylvania and Director of the Allegheny Observatory. In June of the same year he married Miss Matthews, a niece of Captain Floyd, President of the Lick Trust, with whose family she had lived on Mt. Hamilton.

Keeler's work at the Lick Observatory, of which more will be said in what follows, was continued in a most effective manner with the modest instrumental resources at Allegheny. His work here might well serve as an object lesson to those who complain of their inability to obtain useful results because they do not happen to have instruments of the largest size at their disposal. With a full understanding of the art of making the most of his means, he took up photography for the first time, made himself thoroughly familiar with photographic processes, and then, with the aid of a spectrograph whose general design has been followed in the construction of the great modern spectrographs at Mt. Hamilton, Potsdam, Pulkowa and Williams Bay, he obtained the photographs of the spectra of red stars which excited so much interest at the dedication of the Yerkes Observatory. He also made an admirable series of drawings of Mars, which was published in the *Memoirs* of the Royal Astronomical Society. In 1893 he accompanied the writer on an astrophysical expedition to Pike's Peak, where his experience and assistance were invaluable. In the same year, in company with Professors Crew and Ames, he joined me in editing the astrophysical part of *Astronomy and Astrophysics*. The *Astrophysical Journal* was established in 1895, and Keeler became joint editor with myself of the new publication. Until his return to Mt. Hamilton in 1898, where distance prevented him from taking an active part in the editorial work, he gave much time to the Journal, which owes much to his labors.

Keeler's spectroscopic proof of the meteoric constitution of Saturn's rings was made at Allegheny in the spring of 1895. In October, 1895, at the writer's request, he made at Cambridgeport the tests of the 40-inch object-glass of the Yerkes telescope which led to its final acceptance. Two years later, at the dedication of the Yerkes Observatory, he delivered an excellent address 'On the Importance of Astrophysical

* A peak in the Mt. Whitney range was named 'Keeler's Needle.'

Research and the Relation of Astrophysics to other Physical Sciences.' In the spring of 1898 he had practically decided to accept a position on the staff of the Yerkes Observatory, and would have done so had he not just then been appointed Director of the Lick Observatory. Strenuous efforts were made by the citizens of Allegheny to retain him, and a project for a new Allegheny Observatory was set on foot by Dr. J. A. Brashear, who has since carried it to a successful conclusion, though at the time in question it was impossible to raise the necessary funds. At the Yerkes Observatory our regret in losing so able and genial a coadjutor was tempered by the feeling that the cause of science would undoubtedly be best advanced by placing such a man in charge of the great institution on Mt. Hamilton.

This view has been most amply justified by the recent work of the Lick Observatory, which has attained the highest degree of efficiency under Keeler's administration. The activity of the Observatory in various fields of research, and the uniform excellence of observations made by men working under the inspiration of able leadership, have been recognized by all who keep in touch with astronomical progress.

But Keeler's recent work on Mt. Hamilton has not been confined to the direction of the affairs of a great observatory. The remarkable success of his experiments with the Crossley reflector, of which a full account is fortunately preserved in the June number of the *Astrophysical Journal*, has impressed everyone who has seen the wonderful photographs of nebulæ and star clusters made with this instrument. The record of this work, like that of many other events in Keeler's career, is full of instruction to those who aspire to achieve success as investigators. When entering upon his duties at Mt. Hamilton, Keeler called together the members of the staff to confer upon the observations to be undertaken. It is customary to divide the nights of the week with the great telescope among several observers, each of whom is pursuing a certain class of observations. When the division had been completed it was remarked with surprise—for the privilege of using such a telescope is highly valued—that Keeler had taken no nights for himself. On the contrary, instead of benefiting by the advantages which must have resulted from the use of the powerful and perfect refractor, he had chosen the difficult and rather uninviting task of bringing into use the Crossley reflector, an instrument of great optical power, but provided with a mounting of such design and construction as to render it almost unfit for exacting work. Although transferred from England to Mt. Hamilton several years before, no results had been obtained with this telescope in its new location. The reflector was best adapted optically for the photography of faint nebulæ, but mechanically it was not adequate for such work which more than any other demands a mounting of the highest stability and perfection of detail. The story of how obstacle after obstacle was encountered and overcome is modestly told in the paper to which reference has been made. The resulting photographs of nebulæ far surpass any similar photographs ever before obtained, and reveal new and unexpected features of the first importance. Hundreds of hitherto unknown nebulæ were discovered on the plates, and from an examination of these a fact of great significance was established, viz: that the majority of the nebulæ are spiral in form. It has long been known that certain of these cloud-like masses, from which the stars are supposed to be formed, show a spiral structure, but these were considered to be exceptions, and by no means type objects. As the result of Keeler's work it does not appear improbable that future theories of stellar evolution will

start from the spiral rather than from the sphere of La Place's nebular hypothesis.

Of Keeler's other contributions to science two in particular deserve present mention: his determination with the Lick telescope of the motion in the line of sight of the planetary nebulæ and his demonstration of the meteoric constitution of Saturn's rings. The memoir which describes the first of these investigations already ranks as a classic of astrophysical literature. From the well-known principle of Doppler, the lines in the spectrum of a moving luminous object are displaced toward the violet or red according as the motion is directed toward or away from the observer. The spectrum of the planetary nebulæ consists of a small number of bright lines, which under high dispersion are widely separated from one another, but not greatly weakened in intensity. Keeler was the first to take advantage of this fact by using in the powerful spectroscope, designed by himself for the Lick telescope, a closely ruled Rowland grating. With the great dispersion of the fourth order spectrum, he was able to measure the positions of the nebular lines with an accuracy far surpassing that attained in any previous observations of these faintly luminous objects. The resulting velocities of the nebulæ in the line of sight were on the average considerably smaller than the extreme values, of which the greatest motion of approach was that of the nebula *G. C.* 4373, 40.2 miles per second, while the greatest motion of recession was 30.1 miles per second, for the nebula *N. G. C.* 6790. It was also found that the distance between the Great Nebula of Orion and the Sun is increasing at the rate of about 11.0 miles per second. On account of the thorough manner in which this research was planned, the skill exhibited in designing the spectroscope for the Lick telescope, the care taken in executing the measures and eliminating possible sources of error, and the completeness of the discussion of the observational material, Keeler's memoir on this subject in Volume III of the *Publications of the Lick Observatory* takes rank with the best examples of astrophysical literature.

The spectroscopic demonstration of the meteoric constitution of Saturn's rings is perhaps the most striking of the many effective applications which have been made of Doppler's fruitful principle. It has already been pointed out that the displacement of a line is proportional to the velocity of the luminous source. If an image of Saturn is formed on the slit of a spectroscope placed parallel to the planet's equator it is evident that all the lines in the photograph of the spectrum will be slightly twisted out of the vertical position they would occupy if the planet were not rotating on its axis. The displacement due to the rotation increases uniformly from the center of the disk to the circumference, and the lines, though inclined, remain perfectly straight. If the rings were solid, forming a continuous mass with the ball of the planet, it is evident that the spectral lines would be direct extensions of those due to the disk. But Keeler found from a study of his photographs that in passing from the spectrum of the disk to that of the rings the lines were not only displaced as a whole, but twisted in the opposite direction. In other words, it appeared that the velocity of rotation of the inner edge of the ring is greater than that of the outer edge, a result evidently incompatible with the existence of a solid ring, but perfectly in harmony with what must be true if the rings consist of swarms of discrete particles. Careful measurements of the photographs furnished the first direct confirmation of the early theoretical researches of Maxwell, who had shown mathematically that the rings could not exist as solid bodies.

Much more might be said of Keeler's work, but this should suffice to indicate its

lasting value. It is a satisfaction to add that its merit has been widely appreciated, as has recently been evidenced by the award of the Draper and Rumford medals. Keeler was president of the Astronomical Society of the Pacific and a councilor of the Astronomical and Astrophysical Society of America. He was elected an Associate of the Royal Astronomical Society in 1898 and a member of the National Academy of Sciences at its last meeting. His kindly and genial manner, combined with unusual tact and rare judgment, drew to him many friends, who will long mourn his loss.

GEORGE E. HALE.

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*ADDRESS OF THE PRESIDENT BEFORE THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.**

I.

TWENTY-SEVEN years ago the British Association met in Bradford, not at that time raised to the dignity of a city. The meeting was very successful, and was attended by about 2000 persons—a forecast, let us hope, of what we may expect at the present assembly. A distinguished chemist, Professor A. W. Williamson, presided. On this occasion the Association has selected for the presidential chair one whose attention has been given to the study of an important department of biological science. His claim to occupy, however unworthily, the distinguished position in which he has been placed, rests, doubtless, on the fact that, in the midst of the engrossing duties devolving on a teacher in a great university and school of medicine, he has endeavored to contribute to the sum of knowledge of the science which he professes. It is a matter of satisfaction to feel that the success of a meeting of this kind does not rest upon the shoulders of the occupant of the presidential chair, but is due to the eminence and active co-operation of the men of science who either preside over or engage in the work of the nine or ten sections into which the Association is divided, and to the energy and ability for organization displayed by the local secretaries and committees. The program prepared by the general and local officers of the Association shows that no efforts have been spared to provide an ample bill of fare, both in its scientific and social aspects. Members and Associates will, I feel sure, take away from the Bradford meeting as pleasant memories as did our colleagues of the corresponding Association Française, when, in friendly collaboration at Dover last year, they testified to the common citizenship of the Universal Republic of Science. As befits a leading center of industry in the great county of York, the applications of science to the industrial arts and to agriculture will form subjects of discussion in the papers to be read at the meeting.

Since the Association was at Dover a year ago, two of its former presidents have joined the majority. The Duke of Argyll presided at the meeting in Glasgow so far back as 1855. Throughout his long and energetic life he proved himself to be an eloquent and earnest speaker, one who gave to the consideration of public affairs a mind of singular independence, and a thinker and writer in a wide range of human knowledge. Sir J. William Dawson was president at the meeting in Birmingham in 1886. Born in Nova Scotia in 1820, he devoted himself to the study of the geology of Canada, and became the leading authority on the subject. He took also an active and influential part in promoting the spread of scientific education in the Dominion, and for a number of years he was principal and vice-chancellor of the McGill University, Montreal.

SCIENTIFIC METHOD.

Edward Gibbon has told us that diligence and accuracy are the only merits

* Given at Bradford on September 5, 1900.