George Ellery Hale: The Thirteenth Bruce Medalist

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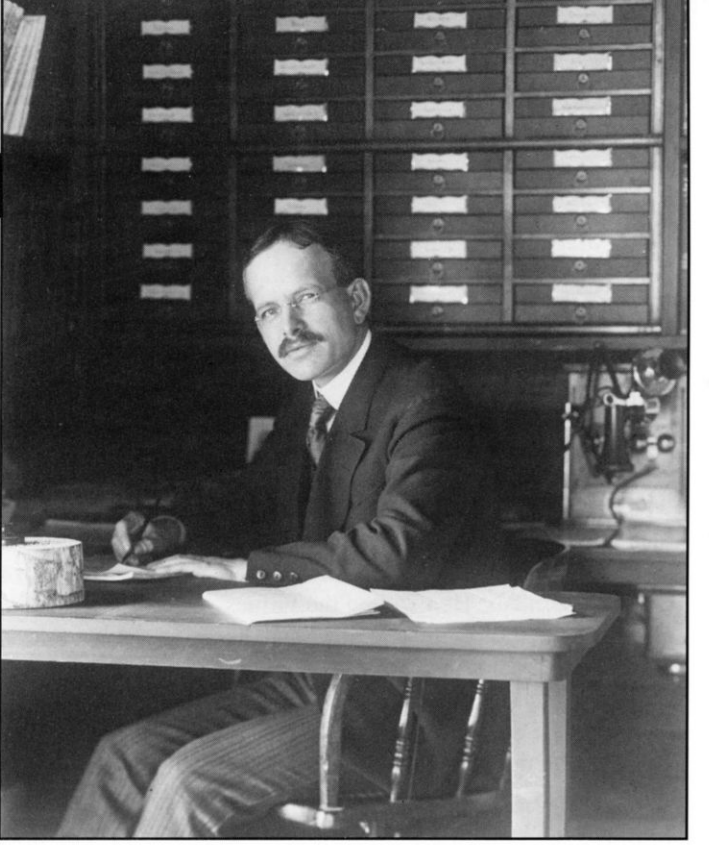

George Ellery Hale
29 June 1868 - 21 February 1938
1916 Bruce Medalist

(Photograph courtesy of Hale Observatories)

George Ellery Hale was born just nine years after two major scientific events: the publication of Charles Darwin's *Origin of the Species,* and the discovery by Gustav Kirchhoff and Robert Bunsen that sunlight, dispersed by a prism or grating, could reveal the chemical composition of the Sun.[1] Hale was raised in an era of optimism influenced by Darwin's great discovery: evolution was destiny, and it would lead to a better, wiser world. It was also an age of altruism. Those who became rich building railroads, steel mills, skyscrapers, and oil companies sought ways to use their wealth for further progress. No one would do more than George Hale to channel this new wealth into scientific research.

Growing up in booming Chicago, George was greatly influenced by his father. As William Hale prospered designing and building elevators for the new skyscrapers, he encouraged his children in all their endeavors. Many years later Hale wrote, "To him I owe my first interest in tools and machinery, an opportunity to pursue the work I liked best, an interest in civic, national and international affairs, and many other advantages."

George grew up interested in everything and built elaborate apparatus for his scientific investigations. By his early teens he had advanced from his first home-made telescope to his own Clark refractor, and he was using it to photograph the Sun and to draw sunspots. Reading Darwin at an early age, he said the book "taught me to regard the Sun as a typical star, a link in the long evolutional chain." This was to be the main theme of his life. The longest of his many books was titled *The Study of Stellar Evolution: An Account of Some Recent Methods of Astrophysical Research.* In it he wrote, "The student who would untangle the secrets of the universe recognizes in the Sun a typical star, placed conveniently within reach and exemplifying the physical and chemical conditions which are repeated in millions of other stars so far removed that they appear to us only as minute points of light. If we are to form a true estimate of the nature of these distant stars, and find the means of tracing out the progressive stages in their development from the nebulae, we must base our investigations upon solar research."

School was not much fun. "Born a free lance, with a thirst for personal adventure, I preferred to work at tasks of my own selection." At 18 he enrolled in the Massachusetts Institute of Technology and announced his engagement to Evelina Conklin, whom he had met during summers in his mother's home town in Connecticut. "I am indebted to the Institute for much valuable instruction, especially in mathematics, physics and chemistry, but I had to find my astronomy elsewhere. The work at the Institute occupied almost every moment of my time, but through the kindness of Professor Edward C. Pickering, I was permitted to spend all available hours at the Harvard College Observatory, where I acted as a volunteer assistant."

During summers he conducted research

1. For more on this discovery see the article on William Huggins in this series in the Sept/Oct 1990 issue of *Mercury*.

at his own private Kenwood Observatory, built adjacent to his parents' house. He ordered the finest equipment available from Pittsburgh instrument-maker John Brashear (who was greatly shocked when he learned that his exacting customer was a teenager). Using a flat movable mirror (a *heliostat*) to reflect the Sun's rays into a grating spectrograph with a focal length[2] of three meters, Hale investigated the spectrum of the Sun and of laboratory sources. He visited Princeton's noted astronomer, Charles Young, who showed him his first solar prominence. Inspired by these experiences, Hale came up with an idea for a new instrument to investigate the Sun. "The principle of the spectroheliograph, which I subsequently found to have been suggested before by Janssen, Braun and Lohse, suddenly suggested itself to me in 1889."

For his senior thesis Hale built the first working spectroheliograph, an instrument for photographing the Sun in the light of one spectral line. As each thin slice of the Sun's image moved across the first slit of a spectroscope, the light from just one wavelength passed through a second, stationary slit. A moving plate holder allowed an image to be built up, slice by slice, of the entire surface of the Sun in the light of that one spectral line. William Hale bought his son an excellent 12-inch refractor to carry the new instrument. George began publishing photographs of solar prominences, flame-like protruberances above the limb of the Sun, made in the light of the strong absorption lines of ionized calcium. These two lines are so close to the violet end of the visible range that astronomers had paid little attention to them, but Hale realized that photographic plates are much more sensitive to these short wavelengths than to longer ones.

After graduation Hale married, visited the Lick Observatory on his honeymoon, and began full-time astronomical research at Kenwood. He discovered clouds on the Sun which he named *flocculi* (now called *plages*). He visited European astronomers, including William Huggins and Henri Deslandres, in part to promote his idea of a new journal to be devoted to astrophysics. He hired photographer Ferdinand Ellerman to assist him at the observatory, and Ellerman took most of the 3000 spectroheliograms accumulated during this period. Hale also organized the astronomical exhibit at the 1892 Colombian Exposition in Chicago, and was appointed associate professor of astrophysics at the new University of Chicago. He was at this point still only 24 years old.

That year he learned that famed telescope maker Alvan G. Clark had two 40-inch glass disks sitting in his shop. They had been ordered by the University of Southern California in a drive to surpass the Lick 36-inch and build the world's biggest telescope. Donors had reneged on pledges when the economy went into a recession, however, and now the disks were available to anyone who could pay for them.

This began a five-year adventure during which young Hale, assisted by University of Chicago president William Harper, persuaded the somewhat disreputable Chicago streetcar magnate Charles Yerkes to put up the funds, first for the lenses and their grinding, then for the construction of the mount and its 63-foot tube, and finally for the magnificent building, designed by Hale, of what we now know as the Yerkes Observatory. Placed in Williams Bay, Wisconsin, away from the lights of Chicago, it included many innovations. According to Hale, "One of the principal aims of the Observatory is to bring together the physical and astronomical sides of the work. Therefore the building will be provided with laboratories for optical, spectroscopic and chemical work, concave grating rooms, large dark rooms, developing, emulsion and enlarging rooms, a galvanometer [electronics] room and the large heliostat room."

In the meantime the Hales spent a semester in Germany, where George at first intended to earn a doctorate, but "my digestion could not meet the demands of German food. Thus I could not earn a German degree..." Besides, there was much to do back home. Hale founded the *Astrophysical Journal* in 1895, with himself and spectroscopist J. Edward Keeler as co-editors and Hale as chief fundraiser. By the time the Yerkes Observatory opened in 1897 he had hired an outstanding staff, including Edward E. Barnard, Sherburne W. Burnham, and George Ritchey, as well as Ellerman. They were soon joined by 22-year-old graduate student Walter Adams. Their work was primarily in spectroscopy (the study of spectra) and instrument development.

In this period Hale was raising funds, designing instruments, hosting European astronomers, playing a major role in the founding of the American Astronomical Society, and trying to keep the peace among the astronomers, and especially their wives, in the isolated and sometimes snowbound community of Williams Bay. A reporter described him as "slight in figure, agile in movement, of high-strung nervous temperament, over-flowing with formulae, technical facts and figures, theoretical speculations, almost ad infinitum. His mind seems made of some stellar substance which radiates astronomical information as a stove sheds heat."

As has every observer since Galileo, Hale soon wanted a bigger telescope. Realizing that refractors had reached their effective limit with the Yerkes 40-inch (to this day the largest ever built), he began planning for a larger reflector. Already in 1894 William Hale had bought his son a 60-inch disk, but a richer benefactor would be needed to figure a mirror and mount it. After an unsuccessful effort to interest University of Chicago founder John D. Rockefeller, Hale was delighted to learn in 1902 that steel magnate Andrew Carnegie was establishing the Carnegie Institution of Washington (CIW) and endowing it with $10 million to be used for research.

He immediately began a campaign to get the CIW to support the construction of a 60-inch telescope. Impatient as always, he set out for Mount Wilson (then called Wilson's Peak) in southern California, already known to be a superb site for reasons of both climate and seeing.[3]

He moved his family to the little town of Pasadena at the foot of the mountain, brought out some of the Yerkes staff at his own expense, and began testing the site and improving a small cottage near the summit.

In 1904 Hale secured the first small grant from the CIW, officially established an observatory on Mt. Wilson as an outpost

2. Focal length is the distance from a lens or mirror to the point where the light converged by it comes to a focus. A grating spectrograph uses a grating, made up of an etched series of hundreds of lines, to disperse light into its component colors. — *Ed.*

3. *Seeing* is a technical term referring to the steadiness of the atmosphere.

of the University of Chicago (largely funded by his own borrowing), and finally, at year's end, received a promise of over $300,000 from the CIW to establish the Mt. Wilson Solar Observatory as an independent observatory with the largest telescope in the world. Also that year he accepted the gold medal of the Royal Astronomical Society (at 36!) and founded the International Union for Cooperation in Solar Research at the St. Louis World's Fair; it would later grow into the International Astronomical Union.

The early years on Mt. Wilson were joyous ones. Hale, Ellerman, Adams, and others simultaneously built and used the new instruments. According to Adams, "In all this work Hale took an active and enthusiastic part, not hesitating to walk down the 9-mile trail in order to ride his bicycle into Pasadena after some needed supplies which he would then carry on his back up the mountain." The Snow horizontal telescope was purchased from the University of Chicago and re-erected on the mountain. Fed by a heliostat, it produced a solar image almost seven inches in diameter.

Influenced both by his own difficulties at Williams Bay and the well-known conflicts at Mt. Hamilton[4], Hale decided that the astronomers and their families would live in Pasadena. Only those currently observing would stay on the mountain in a building named the Monastery; women at that time were not welcome. Also at Pasadena would be shops for instrument construction (Ritchey was put to work figuring the mirror and designing the mount for the 60-inch) and physical and chemical laboratories. The marriage of physics and astronomy was Hale's lifelong goal.

The early years at Mt. Wilson were the most scientifically productive of Hale's career. As he put it, "The immediate imitation in the laboratory, under experimental conditions subject to easy trial, of solar and stellar phenomena, not only tends to clear up obscure points, but prepares the way for the development along logical lines of the train of reasoning started by the astronomical work."

Thus he showed that the spectra of sunspots could be matched in the laboratory by subjecting the gas to a temperature substantially lower than that of the rest of the solar photosphere, and that the splitting of spectral lines in sunspots was exactly that induced by the presence of a magnetic field of a certain strength. This application of the recently-discovered *Zeeman effect* on the Sun was Hale's greatest discovery. Later, after building 60- and 150-foot high tower telescopes to send the Sun's light down to uniformly cool underground spectrographs, he and his team would find the overall magnetic field of the Sun and (in 1925) show that it reverses polarity in each 11-year sunspot cycle.

By the time the 60-inch telescope was complete, in 1908, Hale had already prevailed upon Los Angeles businessman John D. Hooker to fund the purchase of a 100-inch glass disk. It was cast in France just as the 60-inch mirror was being hauled gingerly up the mountain. In 1910 Hale triumphed again: Andrew Carnegie gave another substantial sum to the CIW, in part to pay for the figuring of the mirror and construction of the third "world's largest telescope" to be built under Hale's direction.

Also that year Hale hosted one of the world's great gatherings of astronomers and physicists, the fourth meeting of the Solar Union. The group photo shows seventeen past or future Bruce medalists, plus such other notables as Karl Schwarzschild, Edwin Frost, and physicists F. S. Brackett, Joseph Larmor, and Janne Rydberg. Unfortunately, Hale attended very little of the meeting because he was too ill with his first nervous breakdown.

Perhaps it was not surprising, considering the number of things he had on his mind and the way he drove himself. Harold Babcock reported that the men in the shop "used to say if Mr. Hale comes in here and wants something, he wants it yesterday!" Babcock also said, "He had the gift of inspiration in an extraordinary way. You could talk to him for ten minutes, and leave him, feeling as though you were walking on air, able to do anything. In any research project his mind leaped ahead to see the possibilities. He was far in advance of anyone else. His excited interest in everything was conveyed to all with whom he came in contact."

The 1910 breakdown left him unable to work for over a year. The Hales went to Europe where he tried unsuccessfully to stay out of the struggles to get the French glass-making firm to cast a new disk (in the end the first disk was used, but not without a change of opticians [5]) and to get Hooker to pay what he had pledged. He visited Egypt in time to watch the opening of King Tut's tomb, and in Florence he looked at the Sun through one of Galileo's telescopes.

In 1914 Europe went to war, and it was apparent to Hale that the United States would eventually be drawn in. Although still ill, he urged the National Academy of Sciences, of which he was foreign secretary, to prepare to provide scientific advice to the government. This led to the establishment of the National Research Council and, for Hale, to three years in Washington, where, as its chairman, he directed the war efforts of the nation's scientists. Afterward he persuaded Andrew Carnegie to put up $5 million to build and endow a permanent home in Washington for the Academy and its Research Council, and he helped design the building. He founded the *Proceedings of the National Academy of Sciences*, and he helped establish the International Council of Scientific Unions. He also persuaded the Rockefeller Foundation to establish the Research Council fellowships which were to prove so beneficial to the development of quantum physics.

Hale wanted to make Pasadena a cultural and scientific center. He served on its planning commission and helped design its civic center. When he joined the board of trustees of the Throop Polytechnic Institute in 1906, it included an elementary school, an art school, domestic science, and manual training courses. Under his powerful stimulus, it dropped all but college-level science and engineering, and in a few decades became the world-class institution for scientific research now called the California Institute of Technology.

Hale was greatly interested in and knowledgeable about the arts, a legacy from his mother. "Naturally I do not share the common fallacy of an antagonism be-

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4. For more on the quarrelsome early days at the Lick Observatory on Mt. Hamilton, see the book *Eye on the Sky*, by Donald Osterbrock and co-authors. (1988, Univ. of California Press.) — *Ed.*

5. For more on the difficult relations between Hale and Ritchey see Donald Osterbrock's *The Pauper and the Prince: George Willis Ritchey, George Ellery Hale, and the Big American Telescopes* (University of Arizona Press, 1992).

tween science, literature and art, which appeal to me in much the same way." He talked Henry Huntington into leaving his enormous collection of books, manuscripts, and paintings to found the Huntington Library and Art Gallery, and served on its first board.

Hale's astronomical interests were hardly limited to the Sun. He brought J. C. Kapteyn to Mt. Wilson for many years, and he encouraged Frederick H. Seares to observe stars that fit into Kapteyn's plan of selected areas. He hired such bright young men as Harlow Shapley and Edwin Hubble shortly after they received their doctorates, and he was delighted when their work enlarged the scale of the known universe. When Shapley's study of globular clusters led to a new model of the Galaxy, Hale sponsored what later became known as the Shapley-Curtis "Debate" before the National Academy of Sciences in 1920, in which two leading astronomers debated the size and uniqueness of our Galaxy.

But after the war Hale's health was precarious. Between breakdowns he had to limit himself to a few hours of work per day, and in 1923 he turned over the directorship of Mt. Wilson to Adams. To do the work he loved without getting in the way of others, he built his last observatory, a small private one in Pasadena, where he visually observed solar flares and prominences with a new spectrohelioscope he devised.

He continued writing. In a 1928 *Harper's Magazine* article, "The Possibilities of Large Telescopes," he proclaimed, "While much progress has been made, the greatest possibilities still lie in the future." Hale was soon back to his old ways, convincing the Rockefeller Foundation to put up the $6 million needed to build a 200-inch telescope. The foundations established by millionaires Andrew Carnegie and John D. Rockefeller continued their personal rivalry, so the telescope could not go to the CIW-owned Mt. Wilson Observatory; it was given to Caltech instead. The two Pasadena-based institutions agreed to operate their observatories jointly,[6] and Hale served as chairman of the Joint Observatory Council until his death. He personally helped select the site on Palomar Mountain, and he rejoiced when the giant glass disk reached the optical shop in Pasadena. Another world war intervened, but when the 200-inch telescope was finally dedicated, ten years after Hale's death, it was appropriately named the Hale Telescope. ■

Acknowledgement: Much of this article is based on one of the finest scientific biographies ever written, *Explorer of the Universe: A Biography of George Ellery Hale*, by Helen Wright.

6. From 1969-80 the jointly-operated observatories were known as the Hale Observatories. There was a not-very-amicable divorce in 1980, with CIW keeping Mt. Wilson Observatory and Caltech retaining Palomar Observatory. The former institution has since abandoned Mt. Wilson in favor of its Las Campanas Observatory in Chile; in 1989 it adopted the name of The Observatories of the Carnegie Institution of Washington and purchased 25% of the observing time at Palomar Observatory.