The Hugginses, the Drapers, and the Rise of Astrophysics

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1985

"Twinkle, twinkle, little star. How I wonder what you are." That's how the old nursery rhyme goes. It's one thing to see the twinkling stars, and it's quite another to know what they really are. Starlight was transformed into knowledge of the physical nature of stars in the last century by photography, spectroscopy, and the development of modern physics. It took innovative men and women to make astrophysics possible, and two celebrated husband-and-wife teams—the Hugginses and the Drapers—were among the first to try to make sense of the stars' spectral fingerprints.

Dr. Joseph S. Tenn, professor of physics and astronomy at Sonoma State University, in the wine country of northern California, is a two-time prize-winner in the annual Hughes Aircraft Company Writing Contest: Ten years ago his article, "The Search for Solar Neutrinos" (*Griffith Observer*, August, 1976) was awarded an Honorable Mention. We hope we hear from him sooner than that the next time, but we have been compensated by the efforts of his students. Two of them have also won Honorable Mentions in recent years. He says he is prouder of that fact than his own awards.

This article was written while Dr. Tenn was on sabbatical leave and enjoying the hospitality of the Department of Physics and Astronomy at the University of Massachusetts, Amherst.

On the occasion of an examination of the spectra of coloured flames . . . conducted by Bunsen and myself . . . I made some observations which disclose an unexpected explanation of the origin of Fraunhofer's lines, and authorize conclusions therefrom respecting the material constitution of the atmosphere of the sun, and perhaps also of the brighter fixed stars.

Fraunhofer had remarked that in the spectrum of the flame of a candle there appear two bright lines, which coincide with the two dark lines D of the solar spectrum. The same bright lines are obtained of greater intensity from a flame into which some common salt is put. I formed a solar spectrum by projection, and allowed the solar rays concerned, before they fell on the slit, to pass through a powerful salt-flame. If the sunlight were sufficiently reduced, there appeared in place of the two dark lines D two bright lines; if, on the other hand, its intensity surpassed a certain limit, the two dark lines D showed themselves in much greater distinctness than without the employment of the salt-flame.

. . .I conclude further, that the dark lines of the solar spectrum which are not evoked by the atmosphere of the earth, exist in consequence of the presence, in the incandescent atmosphere of the sun, of those substances which in the spectrum of a flame produce bright lines at the same place. . . the dark line D in the solar spectrum allows us, therefore, to conclude that there exists sodium in the sun's atmosphere.

These words, presented to the Berlin Academy on 27 October 1859 by Professor Gustav Kirchhoff of Heidelberg, were to revolutionize observational astronomy as had no invention since the telescope. (The above quotation is from G. G. Stokes's translation which appeared in the *Philosophical Magazine* in March, 1860.)

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Kirchhoff, working with the chemist Bunsen (inventor of the "burner"), had solved the mystery of the Fraunhofer lines, those missing wavelengths in the spectrum which result when sunlight is spread out by means of a prism or grating. When the light is passed through a slit first, an image of the slit appears in each wavelength in succession, hence a missing wavelength appears as a dark "line."

Starting in 1814, Fraunhofer, the great Munich optician and telescope builder, had mapped out hundreds of these lines and had labeled the brighter ones A, B, C, D, *et cetera* — designations still in use today. Others had studied the lines and had tried to find a connection with the bright lines emitted by hot gases in the laboratory. Some, notably Foucault (of the pendulum), had succeeded, but it was the work of Bunsen and Kirchhoff which led directly to what was called "The New Astronomy," "Astro-Physics," or finally, "Astrophysics."

All this took place just two decades after the philosopher Auguste Compte stated that the composition of the stars would never be amenable to scientific investigation.

The new science was to have many pioneers. Among the most important were two couples — William and Margaret Huggins and Henry and Anna Draper. The four were amateurs; they worked solely for the love of what they were doing. Not one was educated in astronomy. Only Henry Draper had a university education at all. Both couples financed their own research.

In 1860, however, all of this was in the future. Margaret Lindsay Murray of Dublin was 12 years old. She had learned the constellations on long walks with her grandfather, had built her own telescope, and was observing and drawing sunspots on her own.

Her future husband, William Huggins, was 36. He had shown a lively interest in science from the age of five, managing to shock himself with an electrical machine of his own devising shortly afterward. Due to an attack of smallpox, he had very little formal schooling. Private tutors taught him mathematics, classics, and languages (he learned six) at his London home, and he attended lectures and demonstrations in chemistry and physics at the Adelaide Gallery. His interests included chemistry, optics, physics, electricity, and the new science of photography.

At eighteen Huggins bought his first telescope. At the same time he was forced, due to his father's failing health, to take over the family mercery business and to look after his parents. University plans were abandoned. In his spare time he traveled in Europe and pursued two hobbies, microscopy and astronomy. After a period of indecision, he abandoned the former, at least partly because he was too sensitive for some biological work. In 1854 he sold the mercery business and moved himself and his parents to Upper Tulse Hill, then a few miles outside of smoky London, where he would devote the rest of his life to astronomical research.[1] As he wrote many years later

In 1856 I built a convenient Observatory, opening up a passage from the house, and raised so as to command an uninterrupted view of the sky except on the north side. It consisted of a dome 12 feet in diameter and a transit room. There was erected in it an equatorially mounted telescope by Dollond of 5 inches aperture, at that time looked upon as a larger rather than a small instrument. I commenced work on the usual lines, taking transits, observing and making drawings of planets.

. . .In 1858 I purchased from Mr. Dawes an object-glass by Alvan Clark of 8 inches diameter . . .

I soon became a little dissatisfied with the routine character of ordinary astronomical work, and in a vague way sought about in my mind for the possibility of research upon the heavens in a new direction, or by new methods. It was just at this time, when a vague longing after newer methods of observation for attacking many of the problems of the heavenly bodies filled my mind, that the news reached me of Kirchhoff's great discovery of the true nature and the chemical constitution of the sun from his interpretation of the Fraunhofer lines.

Here at last presented itself the very order of work for which in an indefinite way I was looking—namely, to extend his novel methods of research upon the sun to the other heavenly bodies. This was especially work for which I was to a great extent prepared, from being already familiar with the chief methods of chemical and physical research.[2]

Huggins prevailed upon W.A. Miller, a chemistry professor and neighbor, to join him in an attempt to observe Fraunhofer lines in stars. In his words,

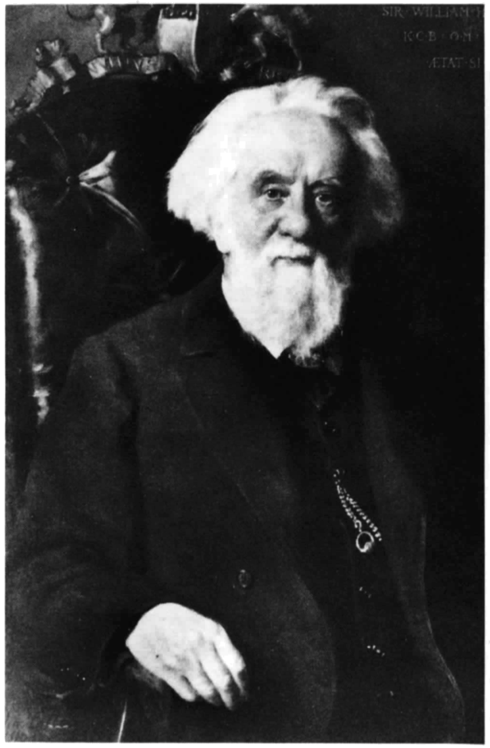
> **Let us look at the problem which lay before us. . . . From the sun, with which the Heidelberg professors had to do — which, even bright as it is, for some parts of the spectrum has no light to spare — to the brightest stars is a very far cry. The light received at the earth from a first-magnitude star, as Vega, is only about the 1/40,000,000,000 part of that received from the sun.**[3]

The spectroscope was attached to the eye-piece of the telescope, and a plano-convex lens was used to spread the star's light in one direction along the slit. Especially difficult was the problem of furnishing a comparison spectrum from the light of a known terrestrial substance. Light from a flame was reflected by prism into the same slit as the starlight, then the two compared visually.

> **Then it was that an astronomical observatory began, for the first time, to take on the appearance of a laboratory. Primary batteries, giving forth noxious gases, were arranged outside one of the windows; a large induction coil stood mounted on a stand on wheels, so as to follow the positions of the eye-end of the telescope, together with a battery of several Leyden jars; shelves with Bunsen burners, vacuum tubes, and bottles of chemicals, especially of specimens of pure metals, lined its walls.**

> **The observatory became a meeting-place where terrestrial chemistry was brought into direct touch with celestial chemistry. The characteristic light-rays from earthly hydrogen shone side by side with the corresponding radiations from starry hydrogen, or else fell upon the dark lines due to the absorption of hydrogen in Sirius or in Vega. Iron from our mines was line-matched, light for dark, with stellar iron from opposite parts of the celestial sphere.**[4]

In February, 1863, another new invention made its appearance in the observatory. Huggins and Miller attempted to photograph the spectra of the stars. The attempt was not successful. Their images of the dispersed light of Sirius and Capella failed to show lines. The wet collodion process was slow, and they could not track the stars precisely enough for the long exposures necessary.



William Huggins (1824-1910) saw only bright lines in the spectra of "unresolved" nebulae and realized he was seeing light from luminous gas in accordance with Kirchoff's laws of spectral analysis. The paper he published in 1863, "Lines of the Spectra of some of the Fixed Stars," demonstrated that chemical elements known on earth could be recognized in the spectra of starlight. Huggins transformed astronomy. (portrait painted by John Collier, 1905, *Astrophysical Journal*, Vol. 37, 1913, p. 144)

Instead, Huggins turned to preparing maps of the spectra of 26 elements using a large induction coil powered by Leyden jars. Miller soon returned to his other duties, and for the next eleven years Huggins worked alone.

In fact, he did very little but work — and take care of his widowed mother. According to his biographers,

> **He renounced all idea of marriage during her lifetime, so that he might remain at home with her, doing his work and above all taking care of her. During her later years he never slept out of the house, and in the evenings he used at intervals of about half an hour to leave his work at extreme inconvenience to go and talk to her.**[5]

During this period Huggins made his greatest discovery:

> **On the evening of August 29th, 1864, I directed the telescope for the first time to a planetary nebula in Draco. . . .I looked into the spectroscope. No spectrum such as I expected! A single bright line only! . . . The riddle of the nebulae was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas.**[6]

For a century astronomers had disputed the nature of the nebulae, the "fuzzy objects" in the sky. William Herschel at first thought them all to be composed of stars and attempted to resolve them with his increasingly powerful telescopes. Kant and Laplace had suggested that there must be interstellar gas clouds which would condense into solar systems, but Kant and others also believed that some nebulae were "island universes," huge systems of stars like the Milky Way seen from enormous distances. When Herschel discovered (and misnamed) planetary nebulae, he concluded that some nebulae were truly gaseous.

Huggins showed that the spectroscope could tell the difference: Some nebulae, including the famous one in Andromeda, have continuous spectra like that of the sun. Resolvable or not, they must be composed of many suns. Others, including the planetaries and the Great Nebula in Orion, exhibit emission lines only. These can only be clouds of gas.

During the 1860s Huggins applied his spectroscope to novae and comets (he detected carbon in the latter), and made the first measurement of star's velocity along the line of sight. His visual observation of the Doppler shift in the lines of the spectrum of Sirius was highly uncertain, however, and it was soon replaced by photographic methods in the hands of H. C. Vogel and others.

In 1866 Huggins was awarded a medal by the Royal Astronomical Society. Two years later his mother died, and it was while mourning her that he missed the opportunity to make another discovery. The French banker-turned-astronomer, P. J. C. Janssen, after spectroscopically observing solar prominences at an eclipse in India, saw them again the next day, without an eclipse, simply by pointing the spectroscope near the sun. J. Norman Lockyer in England independently did the same, and soon Huggins, who had published the idea some months earlier, came up with a new twist: By opening the slit of the spectroscope, he was able to see the whole prominence in the light of one wavelength. This development led to George Hale's invention of the spectroheliscope and to the beautiful photographs of solar prominences so common today.[7]

Meanwhile, what was happening in America? Lewis M. Rutherfurd, attorney and amateur scientist (he had studied some physics and astronomy at Williams College), built an observatory in the center of New York City in 1856, the same year that Huggins built his at Upper Tulse Hill. By 1858 Rutherfurd was making stereographic photographs of the moon, and his observations of stellar spectra preceded those of Huggins (and were themselves antedated in Italy). He exhibited a superb photograph of the solar spectrum in 1864, but he neglected to publish it for some time. A modest man who never asserted his claims to priority, Rutherfurd produced excellent gratings which were used by many of the early spectroscopists.[8]

Of greater interest to us is the Draper family. We must begin with John William Draper. Born and educated in England, he moved his family to Virginia when he was 21. After teaching and experimenting at Hampden-Sidney College, he attended medical school at the University of Pennsylvania and moved to New York to become professor of chemistry at the City University of New York (now NYU) and one of the founding faculty of its medical school. An early experimenter with photography, he took one of the first portraits shortly after word of the Daguerre process reached New York.

In 1840, when his son Henry was three, J.W. Draper took the first photograph of the moon, a rather fuzzy daguerreotype. Three years later he produced the first photograph of a diffraction spectrum. He performed many experiments with light; he photographically discovered ultraviolet spectral lines, and he anticipated several of the discoveries of Bunsen and Kirchhoff. In 1850 he had 13-year-old Henry producing photographic slides through a microscope to illustrate one of his textbooks.[9]

With such a childhood it is not suprising that Henry Draper finished all of his studies for a medical degree at the age of twenty. According to the rules of the University of the City of New York, he could not receive his degree until age 21, and so he and his brother spent the year touring Europe.

Thus it was that Henry Draper attended the meeting of the British Association in Dublin in August, 1857. Afterward he joined a number of others in accepting an invitation to visit Birr Castle, Parsonstown, to see the largest optical telescope ever built by an amateur, the 72-inch reflector of the Earl of Rosse.[10]

The visit had immediate impact. Henry had found his calling.

> **On returning home in 1858, I determined to construct a similar, though smaller instrument; which however, should be larger than any in America, and be especially adapted for photography.**[11]

J. W. Draper had prospered. With income from his salary as chemistry professor, his share of the profits of the proprietary medical school, and royalties from three textbooks, he had moved his household — wife, six children, two sisters, and servants — to a country estate at Hastings-on-Hudson, some 20 miles up the Hudson River from New York City.[12] It was here that young Henry built his observatory. Employed first as a physician on the staff of Bellevue Hospital and then as his father's colleague on the university faculty, he must have been busy.

He ground a 15½-inch speculum mirror, but it broke. Fortunately, the senior Draper visited England that year (where he became heavily involved in the debate over Charles Darwin's new theory of evolution), and discussed Henry's problem with John Herschel. Sir John informed him that metal mirrors were passé. Glass was much lighter and easier to grind, and Foucault had shown how to coat it with silver to make a superior mirror. J. W. Draper wrote immediately to his son, and Henry began three glass mirrors, each 15½ inches in diameter.[13]

Thus Henry Draper's astronomical career began with the completion of his first telescope in 1862. But the Civil War intervened. Dr. Henry Draper spent most of that year as a surgeon with the New York State Militia in Virginia.

A fever contracted in the swamps led to an early discharge, and he soon returned to astro-

Henry Draper (1834-1882) was by training and profession a doctor, but his status as an "amateur" astronomer is misleading. His accomplishments in astrophotography and stellar spectroscopy helped establish modern astrophysics. (Annals of the New York Academy of Sciences, Vol. 395, 1982, p. 300).

nomy. He spent the next year continuing his father's work, taking 1500 photographs of the moon and others of the sun and planets. His 1864 article, "On the Construction of a Silvered Glass Telescope 15½ inches in Aperture, and its Use in Celestial Photography,"[14] became a standard reference for telescope makers.

It was during this period that Henry Draper published his first article on spectrum analysis. He also wrote a chemistry textbook (again following in his father's footsteps), and was appointed professor of physiology and dean of the faculty of the medical school.

The year 1867 was an important one for thirty-year-old Henry Draper. On October 28 he married Anna Palmer, the beautiful red-haired daughter of a very wealthy and prominent New York businessman. What the Drapers always referred to as their "wedding trip" was a shopping expedition the next day: They selected the glass that would become the mirror of a 28-inch telescope.[15]

It took five years to build the new instrument. All of the mirror correcting was done by Henry and Anna Draper. In the meantime they produced

The very first photograph ever taken of a star's spectrum was obtained by Dr. Henry Draper **and** *his wife, Anna Palmer Draper. The star was Vega, and the Draper spectrogram clearly showed four dark hydrogen lines. Anna Draper continued to share the responsibility at the telescope, and after her husband's death, Anna Draper propelled astronomy forward — and woman astronomers forward — by financing the Henry Draper Memorial —* The Draper Catalogue of Stellar Spectra *— at Harvard. (Annals of the New York Academy of Sciences,* Vol. 395, 1982, p. 301)

the best photographs yet made of the solar spectrum, and the Drapers became known among the leading hosts of New York City. They spent the academic years in the Palmer mansion on Madison Avenue (between 39th and 40th streets, it was the last house in the city), where Henry installed a laboratory considered the best-equipped in the world. Summers they lived at Dobbs Ferry, just a two-mile carriage ride from the observatory at Hastings-on-Hudson. From the beginning the couple worked together. In the wet-plate era, one of Mrs. Draper's duties was to coat the plates with collodion just before exposure.[16]

Completion of the new telescope brought a triumph. In August, 1872, the Drapers succeeded where Huggins had failed. Assisted by his wife, Henry Draper made the first photograph of a stellar spectrum. Four hydrogen lines could be discerned in the light of Vega.[17]

When Courtlandt Palmer died in 1873, Anna Draper and her three brothers inherited a fortune. Henry Draper resigned as dean of the medical school and took over management of the estate. He remained a professor of chemistry.

In 1874, Henry Draper left his own research to direct the photographic department of the U.S. commission to observe the transit of Venus. He did this job so well that Congress awarded him a special gold medal. In 1878, the Drapers led an expedition to Wyoming to view and photograph a solar eclipse. Among their traveling companions was Thomas Edison.[18]

More precisely, *some* of the party viewed the eclipse. As for Mrs. Draper,

> **Her special duty was to count the seconds during the eclipse and lest the vision might unnerve her, she was put within a tent and therefore saw nothing at all of the wonderful phenomenon. Here she sat patiently and accurately calling out the seconds while the glorious and awe-inspiring spectacle was unfolded.**[19]

(Twenty-two years later Anna Draper finally got to see a solar eclipse. Her research days long behind her, she joined Annie Cannon and others to view the spectacle from a hotel roof in Norfolk, Virginia.)[20]

Using both the 28-inch reflector and a 12-inch refractor purchased from Alvan Clark, Henry Draper photographed stellar and planetary spectra and thought he detected oxygen lines — in emission — in the sun.

The spring of 1879 saw the Drapers in England. There they visited their English counterparts, the Hugginses.

Yes, William Huggins also had found his partner. When we left him in the late 1860s, he was working alone, his only companion a dog named Kepler. At the home of mutual friends he met Margaret Lindsay Murray. As a teenager she had made her own telescope, and, inspired by some unsigned magazine articles, she constructed her own spectroscope and observed the Fraunhofer lines in the sun. Now she met the author of those articles.

In 1869, the Royal Society received a substantial bequest. It was decided to use it to "provide a telescope of the highest power that is conveniently available for spectroscopy"[21] and to place it where it would be put to the best use — at

Lady Margaret Lindsay Huggins did not marry William until 1875, and by then Huggins had already pioneered the "New Astronomy" with his spectroscopic discoveries. Mrs. Huggins soon joined her husband at the telescope and in the laboratory, and together they refined astronomical spectroscopy. They coauthored An Atlas of Representative Stellar Spectra. (photograph taken around 1908, *Astrophysical Journal, Vol. 42,* 1915, p. 1.)

Upper Tulse Hill. William Huggins refused to accept title to the instrument but agreed to use it on loan for as long as he could make effective use of it. During construction Huggins made numerous trips to Dublin to test the telescope at Sir Howard Grubb's establishment — and to visit Margaret Murray.

They were married in 1875. She was 27; he was 51.

Mrs. Huggins was a talented artist and collector who joined her husband in turning Tulse Hill into a showplace. The couple considered themselves poor "for our position," but William owned a Stradivarius violin, and when the American astronomer Edwin Frost visited after William's death, he was awed by the signs of wealth.[22] In the early years, according to Mrs. Huggins,

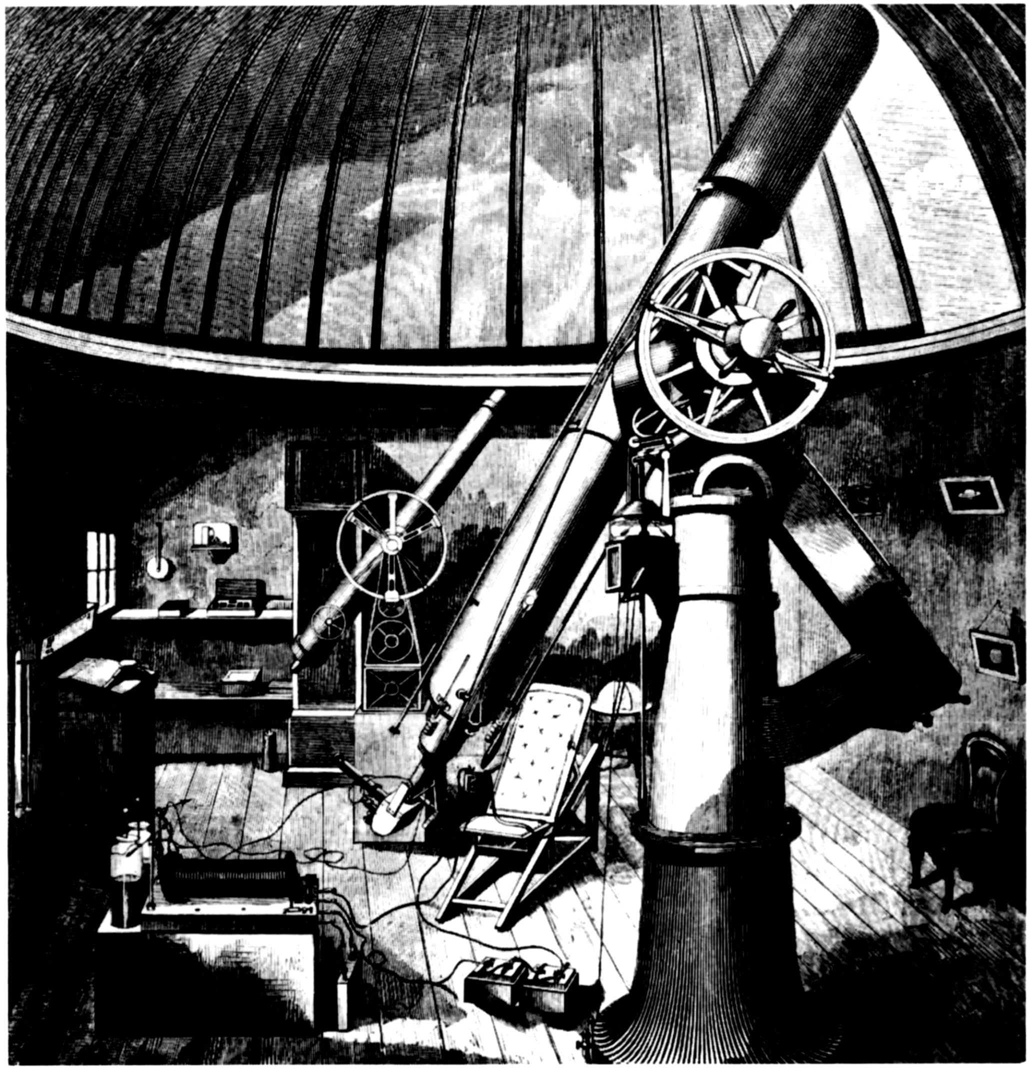
I suppose that no such work ever came from so uncomfortable an observatory as ours. We had not the means to make it comfortable. I was Sir William's only assistant and we both worked harder than hard. One of the compensations was the glorious beauty of the midnight sky, of the skies of the early morning; and no imagination could fail to be struck with the wonders of the heavens sweeping round majestically in perfect peace within five miles of the greatest city and the greatest turmoil of the world.[23]

The new telescope was actually two: A 15-inch refractor and an 18-inch Cassegrain reflector. There was only one mount, and for the first few years only one could be set up at a time. Later they were rigged together in such a way that either could be used at any time. Photographic technology also improved. William wrote much later:

The great and notable advances in astronomical methods and discoveries by means of photography since 1875, are due almost entirely to the great advantages which the gelatine dry plate possesses for use in the observatory, over the process of Daguerre, and even over that of wet collodion. The silver-bromide gelatine plate, which I was the first, I believe, to use for photographing the spectra of stars, except for its grained texture, meets the need of the astronomer at all points. This plate possesses extreme sensitiveness; it is always ready for use; it can be placed in any position; it can be exposed for hours . . .[24]

Of such was the conversation when the Drapers called at Tulse Hill. On their return to America the Drapers would switch to the new dry plates. Huggins listened attentively when Henry Draper presented his discovery of oxygen in the sun to the Royal Astronomical Society, but asked "to be allowed to suspend my judgment a little longer."[25] In this he was wise, as Draper had mistaken gaps between dark absorption lines for bright emission lines. There is oxygen in the sun, but Henry Draper did not discover it.

Most of the research to come out of Tulse Hill was now published under joint authorship of William and Margaret Huggins. Although unusual at a time when even the work of established profes-



The Huggins observatory at Upper Tulse Hill, near London, had a 12-foot dome. The 5-inch Dollond refractor occupies the transit room, in the background here, and the 8-inch Clark-Cooke refractor is mounted in the main dome. This is what the interior of the Huggins observatory looked like between 1860 and 1869. Later, larger instruments were installed. Pictures of planets hang from the wall. (from *An Atlas of Representative Stellar Spectra,* 1899)

sional astronomers went out under the name of the observatory director alone, this was certainly deserved. Mrs. Huggins described her efforts:

This work in winter in favourable weather would begin about 6 p.m. and would continue till 9.30 or 10 p.m. . . . I observe while William looks after clock, dome, etc. When we first began, our exposures on each star had to be very long. I have, I think, worked on one for about three hours. But in our later work from three quarters to one and a half hours would be about the time. I had to teach myself what to do by degrees: at first I had my difficulties, but now my eyes are trained and are very sensitive. Also my hands respond very quickly and delicately to any sudden necessity. I can go and stand well at good heights on ladders and twist about well. (Astronomers need universal joints and vertebrae of india rubber). . . As I observe,

I direct William as to what I need and he moves me bodily on my ladder, so that I am not disturbed more than is necessary.[26]

On her work in the laboratory, she reported

Here the work may be of various kinds. It may be photographic, in which case I should help in arranging instruments, keeping the light right, and so on, if we are working on the sun. If working electrically, I should work batteries, fix electrodes, and be generally handy. I may take a turn at mixing up chemicals, pounding, weighting, dissolving, boiling—in short be a jack of all trades. . . .

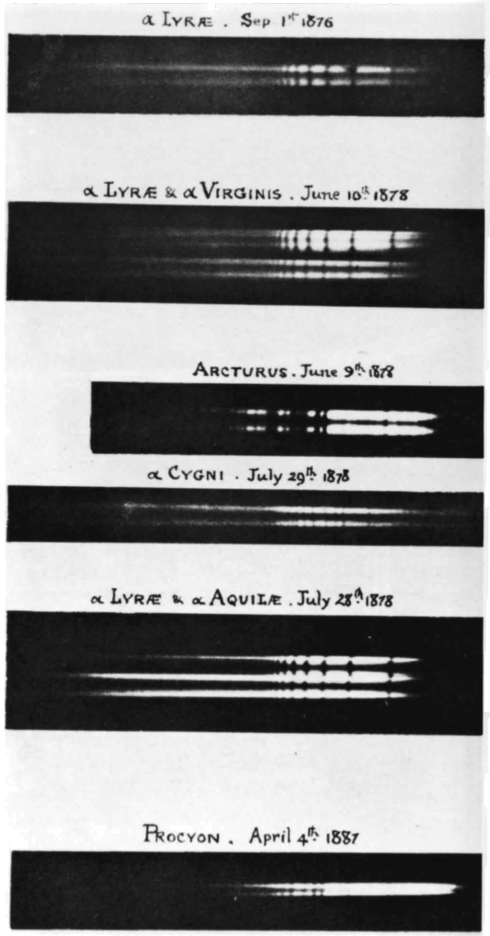
When needful I dust and wash up the laboratories, for no housemaid is allowed into those sacred precincts. I am a capital scientific housemaid. His pet bottles I let William deal with himself, as he will then know where to find them. I used to clean up the steam engine, but I have not for some time felt so able as I used for housemaiding, and William now gets a man to give it a rub up now and then. But I understand about it and can do it at need. One is interesting with a lump of engineer's waste in one hand and some nasty oily stuff in a can in the other.[27]

It wasn't all work. They traveled in Europe, where William took photographs and Mrs. Huggins sketched. Later, as William aged, he spent his holidays fishing. He was a friend of Izaac Walton.

On returning to New York in July, 1879, Henry Draper resumed his research with renewed vigor. He obtained the first photograph of the Great Nebula in Orion on September 30, 1880. It was not very clear, but he soon took better ones. He wrote to E. S. Holden, "The exposure of the Orion Nebula required was 50 minutes; what do you think of that for a test of my driving clock?" Within a few months he was declaring "the singular proposition is therefore tenable that we are on the point of photographing stars fainter than we can see with the same telescope."[28]

He began to work on the *classification* of stellar spectra, a field pioneered by the Jesuit astronomer P. Angelo Secchi at Rome. Draper noted

A preliminary examination shows at once that these stellar spectra are divisible into two groups — first, those closely resembling the solar spectrum; and, second, those in which there are relatively but few lines and these of great breadth and intensity. The photographs of the spectra of Arcturus and Capella are so similar to the solar spectrum that I have not up to the present detected any material differences. But, on the other hand, the spectra of Vega and Alpha Aquilae are totally different. . . .[29]



Here, at last, are some of those representative stellar spectra from the Atlas *William and Margaret Huggins assembled. Absorption (dark) lines show up clearly, and the distinctive pattern evident in the spectra of Alpha Lyrae (Vega) and Alpha Virginis (Spica) is now known to signal the presence of hydrogen.* (from *An Atlas of Representative Stellar Spectra,* 1899)

In the fall of 1882 Henry Draper set out on a two-month hunting trip in the Rocky Mountains. "He was an enthusiastic sportsman and a capital shot, and he entered upon the chase with as much relish as he took a stellar photograph."[30] His party got caught in a snowstorm and was forced to spend a night on an exposed mountain slope. He returned to New York very weak.

The National Academy of Sciences held its November meeting in New York, and, as was the custom, a highlight was to be an elegant banquet at the Draper (formerly Palmer) mansion.

In order to offer a scientific novelty, he (Henry Draper) determined to light the table with the Edison incandescent light, the current being supplied from the dynamo machine in his laboratory; but the source of the power being a gas engine, and therefore intermittent in its action, a disagreeable pulsation was observable in the light. To obviate this he contrived an ingenious attachment to the engine whereby, at the instant at which the speed was increased by the explosion of the gas in the cylinder, a lateral or shunt circuit, the resistance of which could be varied at pleasure, should be automatically thrown in. With his admirable mechanical skill, Dr. Draper extemporized the device from materials at hand and found it to work perfectly. The dinner was given on the evening of November 15th, and was one of the most brilliant ever given in New York; about forty academicians, together with a few personal friends, sitting at the table. Dr. Draper's overwork, however, now told upon him; slightly indisposed as he had been before, he was unable to partake of food and a premonitory chill seized him while at the table.[31]

Five days later he was dead of pneumonia at 45.

William and Margaret Huggins continued to do astronomical research until 1908, when he was 84. He asked the Royal Society to reclaim its telescopes and suggested they be placed at Cambridge University. Sir Howard Grubb, who had built and installed the instruments more than three decades earlier, supervised their removal. He wrote,

It was characteristic of the man that, once he found that the physical powers necessary to carry on active observations had begun to fail, he without delay made arrangements to hand over the instruments for erection in a position and in surroundings such as he thought would be most likely to ensure full advantage of their capabilities.[32]

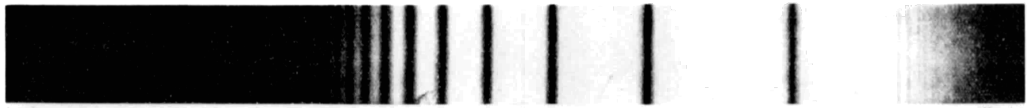
Many awards came to William Huggins. The man who had never attended a university received honorary doctorates from more than half a dozen. The Royal Astronomical Society and the Royal Society honored him with gold medals and with their presidencies. Distinguished visitors, among them the emperor of Brazil, came to Tulse Hill.

In 1897, Queen Victoria honored both Hugginses: "Knighthood of the Order of the Bath was conferred upon William Huggins for the great contributions which, with his gifted wife, he had made to the new science of astro-physics."[33] Thus the magnificent volume, *An Atlas of Representative Stellar Spectra,* published in 1899, is by "Sir William and Lady Huggins."

William Huggins died May 12, 1910. Lady Huggins survived him by five years, during which she continued to host visiting astronomers. She left her books and some instruments to Wellesley College, in recognition of the fact that the Massachusetts institution was educating women in astronomy. Her estate, some 12,000 pounds, she left to schools and colleges, including a women's college, and for memorials to Sir William.[34]

Our story is not over. At the memorable banquet just before his death Henry Draper had found strength to discuss stellar spectra with Edward C. Pickering, the 36-year old physicist and director of the Harvard College Observatory.[35] The discussion was a harbinger of the greatest contributions to astronomy of the Draper family, which were yet to come.

These contributions were made by Anna Draper, and they were made, not with a telescope or spectroscope, but with a checkbook. Determined to carry on her husband's work and unable to find suitable assistants with whom to operate the observatory, Mrs. Draper gave Harvard the telescopes and what eventually grew to be several hundred thousand dollars. With this bounty Pickering hired a gifted group of astronomers, most of them women, and put them to work on a grand plan — the Henry Draper Memorial. *The Draper Catalogue of Stellar Spectra* was published in 1890. Primarily the work of Williamina Fleming, it included spectral classifications of



The first star to have its spectral portrait recorded was Vega, in the constellation of Lyra the Harp. Dr. Henry Draper and his wife Anna did it in August, 1872, and recorded four of the hydrogen lines before William Huggins succeeded in photographing a stellar spectrum. In time, William Huggins was doing it, too, and learning about the physical nature of the stars while he was at it. This is one of his later attempts on Vega, with a fine appearance by the Balmer series of hydrogen lines (dark) in absorption. (from *Splendour of the Heavens,* by T.E.R. Phillips and W.H. Steavenson, New York: Robert M. McBride & Company, 1932)

more than 10,000 stars. Mrs. Draper followed the work closely and visited the observatory often.[36]

This was only the beginning. Henry Draper's niece, Antonia Maury, joined the project after studying chemistry and mathematics at Vassar. She produced detailed analyses of the spectra of 681 bright northern stars. Miss Maury discovered a difference in line widths in the spectra which led directly to Einar Hertzsprung's classification of stars into giants and main sequence stars, and then to that now-ubiquitous tool of stellar astronomy, the Hertzsprung-Russell diagram.[37]

As Mrs. Draper's largess continued the Henry Draper Memorial grew. Annie Cannon joined the staff at Harvard. Miss Cannon took charge of what became the Henry Draper Catalogue and eventually classified the spectra of more than 300,000 stars! The project outlived both Pickering and Mrs. Draper (she died in 1914) and became the standard reference for astronomers throughout the world.[38] With the development of quantum physics in the 1920s it became possible to determine the composition of the stars in detail.

Today we know more about what stellar atmospheres are made of than we know about the composition of the earth's interior. Much of the science that led to this knowledge can be traced to the two couples who spent so many hours together in the observatory.

Notes

[1]Mills, Chas. E. and C. F. Brooke. *A Sketch of the Life of Sir William Huggins, K.C.B., O.M.* London, 1936. [Begun by Mrs. Huggins, this book was continued by John Montefiore and concluded by Mills and Brooke. No author is listed on the title page.]

[2]Huggins, Sir William and Lady. *An Atlas of Representative Stellar Spectra.* London: William Wesley and Son, 1899, pp. 6-7. [Much of the material in this book, including most of the paragraphs quoted, appeared earlier in Huggins, William, "The New Astronomy: A Personal Retrospect," *The Nineteenth Century,* Vol. XLI, 1897, pp. 907-929]

[3]*Ibid,* p. 7.

[4]*Ibid,* p. 8.

[5]Mills and Brooke, p. 27.

[6]Huggins, p. 11.

[7]Clerke, Agnes. *History of Astronomy during the Nineteenth Century,* 3rd ed. London: Adam and Charles Black, 1893, pp. 210-212.

[8]Gould, B. A. "Lewis M. Rutherfurd," *Biographical Memoirs of the National Academy of Sciences,* vol. III. Washington, D.C., 1895.

[9]Fleming, Donald. *John William Draper and the Religion of Science.* New York: Octagon Books, 1972.

[10]Plotkin, Howard. "Henry Draper, Edward C. Pickering, and the Birth of American Astrophysics," *Annals of the New York Academy of Sciences,* Vol. 395, 1982, pp. 321-330.

[11]Draper, Henry. *Smithsonian Contributions to Knowledge,* Vol. 14. Washington, D.C., 1864, p. 1. (Quoted in Plotkin.)

[12]Fleming, p. 31

[13]Barker, George F., "Henry Draper," *Biographical Memoirs of the National Academy of Sciences,* vol. III, Washington, D.C., 1895, pp. 86-87.

[14]Draper.

[15]Plotkin, p. 324.

[16]Cannon, Annie J., "Mrs. Henry Draper, "*Science,* Vol. 41, 1915, p. 380.

[17]Jones, B. Z. and L. G. Boyd, *The Harvard College Observatory,* 1839-1919. Cambridge, Mass.: Harvard University Press, 1971, p. 213.

[18]Barker.

[19]Cannon, p. 380. (Quoted in Jones and Boyd, p. 215.)

[20]*Ibid.*

[21]Presidential Address, Royal Society, 1869, quoted in Dyson, F. W., "Sir William Huggins," obituary notice in *Proceedings of the Royal Society of London,* Vol. 86, 1912, p. ix.

[22]Frost, Edwin Brant. *An Astronomer's Life.* Boston and New York: Houghton Mifflin, 1933, p. 158.

[23]Mills and Brooke, p. 37.

[24]Huggins, p. 21.

[25]Reported in *The Observatory,* Vol. 3, 1879, p. 73. (Quoted in Jones and Boyd, p. 216.)

[26]Mills and Brooke, p. 38-40.

[27]*Ibid,* pp. 41-42.

[28]Quoted in Whitney, Charles A., "Henry Draper," in *Dictionary of Scientific Biography.* New York: Charles Scribner's Sons. Vol. 4, 1971, p. 180.

[29]Quoted in Barker, p. 105.

[30]*Ibid,* p. 134.

[31]*Ibid,* p. 135.

[32]Mills and Brooke, p. 59.

[33]Richardson, Robert S. *The Star Lovers.* New York: Macmillan, 1967, p. 160.

[34]*Nature,* Vol. 95, 1915, p. 278; Jones and Boyd, p. 480.

[35]Jones and Boyd, pp. 217-220.

[36]*Ibid.*

[37]*Ibid,* pp. 236-242.

[38]*Ibid.*

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