Alfred Fowler, born Mar. 22, 1868, died June 24, 1940, received the ASP's Bruce Medal in 1934 for his research achievements. (He is not to be confused with William Alfred Fowler, the 1979 Bruce Medalist.) Photo courtesy of Peter Hingley and the Royal Astronomical Society.

Alfred Fowler

The Twenty-Ninth Bruce Medalist

Alfred Fowler (1868–1940) was one of the first to discover molecules in stars, and he made important contributions to the early development of quantum mechanics.

Joseph S. Tenn
Sonoma State University

Norman Lockyer needed an assistant. By 1885 he had worked his way up from civil-service clerk and amateur astronomer to director of the Solar Physics Observatory and professor at the Royal College of Science in London. Lockyer had discovered the solar chromosphere and a new element, as yet found only on the Sun — to which he had given the name *helium*, "Sun-stuff." So what if most scientists ridiculed his theoretical models? He still hoped to prove that stars and nebulae form from the condensation of meteors, and that atoms break down into simpler particles at high temperatures. But he was nearing 50 and teaching, researching, editing the journal *Nature* (which he had founded), and writing books: *The Chemistry of the Sun*, *Inorganic Evolution*, *Tennyson as a Student and a Poet of Nature*, *The Rules of Golf*. He needed more help.

As his newest assistant Lockyer chose Alfred Fowler, a 17-year-old scholarship student from Yorkshire who was just completing his studies at the college.

It was a perfect match. Fowler brought intelligence, perseverance, and a cool, steady hand to complement the brilliant but impulsive older man. Lockyer put Fowler to work nights as well as days, extending his spectroscopic work from the Sun to more distant stars. He sent the young man on expeditions to obtain spectra of the chromosphere and prominences during solar eclipses.

At first as a teacher-in-training, and later as demonstrator in astronomical physics, Fowler assisted Lockyer until the latter's retirement in 1901, when Fowler was appointed professor of astrophysics in his place. Starting at age 14, Fowler spent 52 years at the institution that has grown from a teachers' college to become the Imperial College of Science, Technology, and Medicine, part of the University of London.

Stars in the Lab

Lockyer's idea that atoms break into simpler particles at high temperatures was based on an important discovery he had made: Some gases emit light at different wavelengths depending on their temperature. Under Lockyer's direction, Fowler investigated how spectra depend on temperature, and in the process the young man discovered numerous new spectral lines. Some of these lines matched previously unidentified lines in the solar spectrum, as Fowler later explained: "Those [lines] found only under the hottest conditions were designated 'enhanced lines,' and the work at once led to the definite assignment of origins to many chromospheric and stellar lines which had previously resisted explanation.… It would scarcely be too much to claim that this further work on enhanced lines introduced a new principle into astronomical spectroscopy, inasmuch as it justified the chemical identification of celestial spectra which could not be completely reproduced in the laboratory."

The spectra of sunspots matched lines from relatively cool materials, while spectra of the prominences contained lines seen only in the hottest gases in the laboratory [see "The Sun," May/June 1991, p. 67]. Although sunlight comes from a mixtures of gases at different temperatures, it soon became clear that sunspots are cooler and prominences hotter than the photosphere, the layer of the Sun that is the source of most solar radiation. The same conclusion was reached by George Ellery Hale (May/June 1992, p. 94) and his colleagues at Mount Wilson in California at about the same time.

The spectrum of Mira (omicron Ceti). Alfred Fowler was the first to identify titanium oxide (TiO) in Mira, a cool, red 'M'-type star. Photo by Walter S. Adams [see "Bruce Medalist Profile," March/April 1994, p. 20] at the Mount Wilson Observatory.

Lockyer's meteoric hypothesis never won support, but his view that spectroscopic differences among stars are primarily due to temperature differences eventually became universal. In 1920, the year of Lockyer's death, Meghnad Saha discovered how the rates of ionization and excitation of atoms in a gas depend on temperature. Soon afterward Cecilia Payne-Gaposchkin [see "Urania's Heritage," January/February 1992, p. 13] and others were analyzing stellar atmospheres.

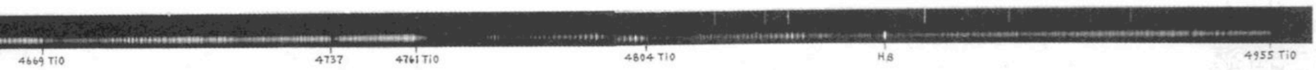
In 19th-century England, scientific assistants were often treated as high-class servants, and it was not uncommon for the head of an observatory to publish all of the work done under his direction as his own. By the time Lockyer retired in 1901, Fowler had labored 16 years and made four eclipse expeditions, yet his name appeared as co-author on just one paper. Even the work he did on an eclipse expedition while Lockyer stayed home was published in the master's name.

Herbert Dingle, a student of Fowler's, later wrote that "the two men were closely associated in researches in astronomy and spectroscopy, the full significance of which became clear only after the development of atomic theory had given an interpretation of the origin of spectra. It was then seen that the classifications of stellar and laboratory spectra made on empirical grounds at [the Royal College], and in the making of which *Fowler took a much more active part than was generally realized at the time*, provided invaluable information on the physical conditions in the sources of luminosity [emphasis added]...."

All that we know of Fowler's own views on this are the handwritten note "My work. A.F." on his copy of an 1897 paper in which Lockyer made no mention of Fowler.

Transitions

On Lockyer's retirement, the solar observatory was separated from the college, and Lockyer continued to use it until it was transferred, against his will, to the University of Cambridge a decade later. By this time, it was hopeless to compete with Hale, whose equipment advantage was as great as his climatological one.



Acknowledging this, Fowler forsook observing and devoted himself to laboratory spectroscopy. In the early years the work was phenomenological, but in 1913 Neils Bohr proposed the quantized atom. According to this theory, the predecessor of modern quantum mechanics, atoms emit or absorb light as they make transitions between discrete energy levels. The quantum of light, or photon, carries exactly the energy difference between the two energy levels.

Fowler's experimental work was important to the development of quantum theory. The astronomer Henry Crozier Plummer noted that "when atomic theory advanced to greater refinement Fowler was in a position to supply the numerical data needed." An important example was when Bohr suggested an explanation for the series of absorption lines in the hot star zeta Puppis which were discovered by and named for Edward Pickering (January/February 1991, p. 26). Bohr said the lines might be due not to hydrogen, but to singly ionized helium. Fowler was skeptical at first, but after Bohr modified his theory, taking into account the motion of the atomic nucleus, Fowler's measurements confirmed it. According to Plummer, the first accurate determinations of the Rydberg constant (a measure of how strongly atoms are bound together) and of the mass ratio of electron and proton came from Fowler's lab.

Fowler had, in Dingle's words, an "uncanny skill in recognizing the identity of celestial spectra and those obtained under vastly different laboratory conditions." It was Fowler who discovered the first molecule, titanium oxide, in the cool 'M' stars (see figure); who, simultaneously with Hale, found magnesium hydride in sunspots; and who identified lines due to carbon monoxide in comet tails. With Robert John Strutt he confirmed that certain absorption lines of near-ultraviolet light are due to ozone in the Earth's atmosphere.

J. Norman Lockyer, founder of Nature, discoverer of helium, and Alfred Fowler's mentor. Like many other prominent scientists of his day, Lockyer treated his assistants like servants and published their work under his name. Similar things continue to happen; in 1974, Antony Hewish received the Nobel Prize for the discovery of pulsars by his graduate student, Jocelyn Bell Burnell. Photo courtesy of Lick Observatory, University of California, Santa Cruz.

Fowler was widely respected as an exceedingly careful experimenter whose measurements would stand as theories came and went. A glimpse of the precision claimed by 1914 is found in a letter from Fowler to W. Wallace Campbell (March/April 1992, p. 62), when Fowler stated that a particular iron line was at 4118.552 rather than 4118.555 Angstroms.

In 1920 Fowler finally received the salary as well as the title of Professor, and just three years later the Royal Society made him one of the first two holders of an endowed Professorship, which freed him from teaching. By all accounts he had been an outstanding teacher, many of whose students went on to success in science and other fields. One was writer H.G. Wells.

Modest and unpretentious, Fowler appears to have been well-liked by his peers and was frequently sought for leadership positions. As the first general secretary of the International Astronomical Union, he wrote most of its constitution and bylaws. But his greatest contribution, as was stated on the bestowal of one of his medals, was to show "that there are no special kinds of matter in any of the celestial bodies, and that the resources of our laboratories are already adequate for the reproduction of most, if not all, celestial species." *m*

JOSEPH S. TENN is a professor of physics and astronomy at Sonoma State University in Rohnert Park, Calif. He is chair of the ASP History Committee. The author is grateful to A.J. Meadows of the University of Loughborough for preserving the manuscript of Fowler's autobiography; to Anne Barrett of Imperial College and Dorothy Schaumberg of the University of California in Santa Cruz for access to Fowler's correspondence; and to David DeVorkin of the National Air and Space Museum for helpful advice. Tenn's email address is joe.tenn@sonoma.edu. Brief biographies of all the Bruce Medalists are available on the World Wide Web at http://yorty.sonoma.edu/people/faculty/tenn/BM.html.