Bruce Medalist Profiles

Ernest W. Brown: The Fifteenth Bruce Medalist

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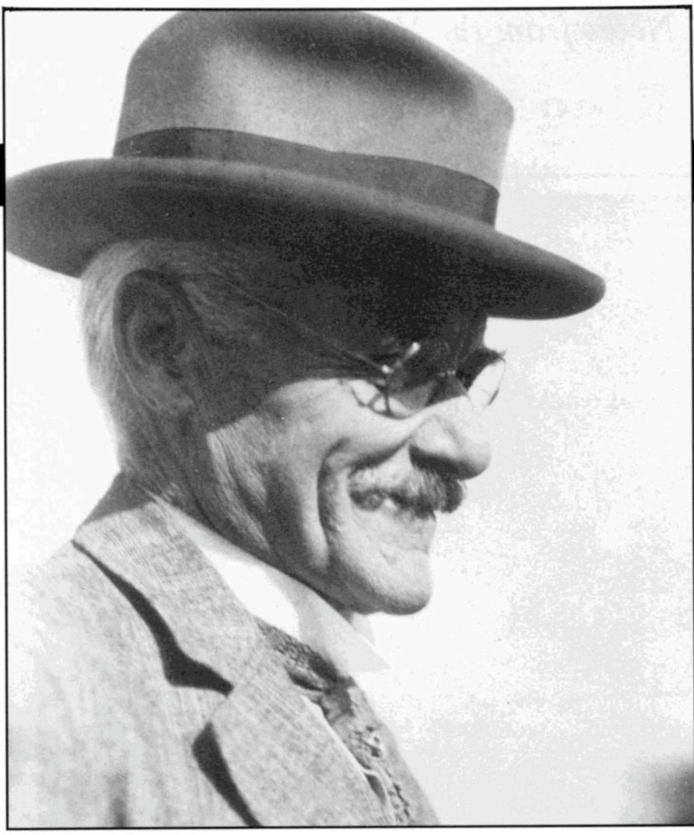


Ernest William Brown
29 November 1866 - 22 July 1938
1920 Bruce Medalist

(Photograph 1929, Yale University, courtesy Dr. Dorrit Hoffleit)

In the 1880s George H. Darwin (son of the biologist) was the Plumian Professor of Astronomy and Experimental Philosophy at Cambridge University. Primarily interested in mathematical problems related to the tides and to the formation of the Earth and Moon, he knew that George William Hill's[1] publications on the Moon's motion were important, but it would be some years before he would find the time to delve into them himself. So he did what professors often do: he asked a student to explore the papers. The student was Ernest W. Brown, and the problem of the Moon's motion would occupy most of his life.

Talented in both music and mathematics, the young man from Hull left Cambridge with an M.A. in 1891 to take a position as mathematics instructor at Haverford College in Pennsylvania. The position carried with it the directorship of the college's observatory, but Brown was no observer. By the time he moved on to Yale University in 1907, he had been promoted to professor, awarded a D.Sc. from Cambridge, made a Fellow of the Royal Society, and elected vice president of the American Mathematical Society. These honors, and many more to come, were for publishing papers with such exciting titles as "On the Part of the Parallactic Inequalities in the Moon's Motion which is a Function of the Mean Motions of the Sun and Moon."

Brown's goal was to calculate the Moon's position at any time, past or future, to within less than a mile, or else to show that Newton's laws of motion and gravity were inadequate to do so. He knew the task would be great; he first spent three years planning the program to make it as efficient as possible. Brown actually finished the theory while at Haverford, publishing it in five parts in the *Memoirs of the Royal Astronomical Society*.

First he solved what he called the "main problem," the motion of the Moon under the attraction of the Sun and Earth only, assuming all three are spherical and that the center of mass of the Earth-Moon system moves in a perfect ellipse with the Sun at one focus. Then he dealt with all the other effects, including the attractions of the other planets and the nonspherical shapes of the Earth and Moon. A portion of the problem, an essay titled *The Inequalities in the Motion of the Moon Due to the Direct Action of the Planets*, won the prestigious Adams Prize of Cambridge University in 1907.

As he explained to the A.S.P. while accepting his medal, "What is known as the 'theory' consists in constructing a set of differential equations which are the symbolic expression of the laws of motion and the law of gravitation, and then in solving them so as to get the three coordinates—the longitude, the latitude, and the parallax [distance]—expressed in terms of a single variable quantity, the time, so that by substituting any given date in the expressions we may obtain these coordinates by straightforward numerical calculation... The chief difficulty comes from the fact that we can only express the results as sums of many hundreds of terms each of which has portions which come from many different parts of the calculations. I can perhaps give an idea of the extent by mentioning that the number of figures written mounted to four or five millions not counting alge-

1. See *Mercury*, Mar/Apr 1991 for more on Hill and celestial mechanics.

braic symbols or the figures which pass through the mind while doing the calculations. This work took nearly 10,000 hours of my own time and that of one computer. In the final results about 1500 terms were left which seemed large enough to be recorded as having an effect to be included when obtaining the position of the Moon at any time. Practically every term is of the form $a \sin (bt + c)$, that is a harmonic function of the time, in which a, b, and c have numerical values which differ from term to term."

The "one computer" was Henry B. Hedrick, who had twenty-two years' experience in astronomical computations, half of them under Simon Newcomb at the Nautical Almanac Office, before joining Brown at Yale. It was the promise of financial support that had brought Brown to Yale. Altogether, the university spent the equivalent of about a quarter of a million dollars in today's currency on the computation and publication of the 660-page tables.

Brown's computations were so good that he concluded that the small discrepancies remaining between calculated and observed positions of the Moon could only be due to fluctuations in time-keeping. The Earth's rotation, whose average period was at that time used to define the unit of time, actually varies slightly. The gradual slowing of the Earth's rotation due to tidal friction had been known, but there are also fluctuations due to the fact that a small rise or fall in the Earth's surface or the deposit of snow in one hemisphere or another produces minuscule changes in the Earth's rotation rate. British astronomer Harold Spencer Jones showed in 1926 that Brown was right: the same irregularities occur in the motions of the Sun and planets, though proportionately smaller as these objects are much farther away than the Moon. In the 1950s noted astronomer Gérard de Vaucouleurs wrote, "In fact as was demonstrated by D. Brouwer and J. van Woerkom, of Yale University, in 1952, these irregularities are apparently perfectly random, i.e., do not seem to follow any other law than the laws of chance; consequently, they must be determined afresh each year through comparison of the observed and computed positions of the Moon obtained from Brown's theory, which is believed to be so perfect as to leave no room for any error other than the apparent one due to faulty timekeeping..."

Brown also investigated other applications of the three-body problem, in particular the Trojan asteroids and the then newly discovered eighth satellite of Jupiter[2]. He tried to understand the Kirkwood gaps in the asteroid belt and similar gaps in Saturn's rings. As Daniel Kirkwood of Indiana University had shown in the nineteenth century, there is an absence of asteroids in orbits where their periods would be simple ratios, such as 3:1 or 7:3, to the period of Jupiter. Brown, following Hill, tried to demonstrate that the missing asteroids had been gradually pulled out of their orbits by Jupiter. This work was extended later by Dirk Brouwer, a Dutch astronomer who became Brown's assistant in 1928 and eventually succeeded him at Yale. Only in the last few years, however, have developments in chaos theory[3] led celestial mechanicians to discover that asteroids in such orbits undergo rapid, chaotic changes in their orbital eccentricity which lead them to near encounters with Mars, which in turn cause them to be ejected from the solar system.

When Clyde Tombaugh at Lowell Observatory discovered Pluto in 1930, Brown helped persuade many that the newfound object was not the massive "Planet X" predicted by Percival Lowell, who had started the original search many years earlier. Brown correctly pointed out that the new planet was not massive enough to account for measurable effects on the motions of Uranus and Neptune. Henry Norris Russell, the dominant figure in American astronomy at the time, finally agreed. Calling Brown "the most distinguished living student of the subject," he wrote, "That so close a set of chance coincidences should occur is almost incredible, but the evidence assembled by Brown permits no other conclusion. Other equally remarkable coincidences have occurred in scientific experience."

Brown's career coincided with the early stages of the gradual conversion from human computers to faster, more reliable mechanical ones, to be replaced later by much faster electronic machines. Already in the 1880s and '90s, while Brown was working out his theory, American inventor Herman Hollerith was producing punched card machines for tabulating censuses and medical records. By the time Brown and Hedrick finished their tables in 1919, Hollerith's Tabulating Machine Company had merged into a new company that would soon change its name to International Business Machines.

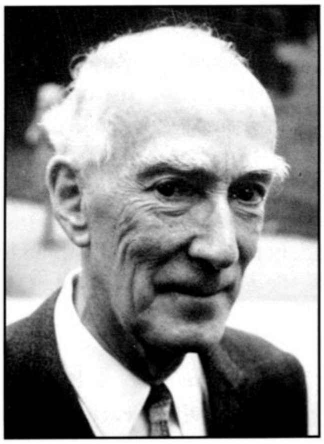
Brown was still active in 1929 when Leslie J. Comrie in London used Brown's tables and half a million punched cards to compute positions of the Moon through the year 2000. Completing the job in just seven months, Comrie found that, "The greater part of the cost was incurred in doing the first ten years, which would have sufficed for immediate needs. But to continue for the next 55 years with a trained and organised staff added very little to the cost, and was certainly more economical than retraining and re-organising ten years later. Moreover, there is little likelihood of Brown's *Tables* being superseded before the end of the century; any acquisition to our knowledge of the Moon during the next seven decades is almost certain to be expressed in the form of corrections to Brown's *Tables*, not in the form of new tables."

He was wrong. In 1960 Brown's tables were abandoned, as electronic computers made the calculations directly from Brown's theory to compute the hourly positions of the Moon for the annual nautical

2. The three-body problem involves calculating the gravitational interactions of three bodies, for example, the Earth, Moon, and Sun. Trojan asteroids are found near the two so-called Lagrange points in Jupiter's orbit, 60° ahead of and 60° behind the planet, where the gravitational forces of the Sun and Jupiter balance so a third object (the asteroid) can stay in a stable orbit. —*Ed.*

3. Under chaos theory, a relatively new branch of mathematics and physics, a very small initial perturbation can lead to a very large change in a body's orbit. —*Ed.*

Jan Hendrick Oort
1900-1992



Renowned Dutch astronomer Jan H. Oort died November 5, 1992 in Wassenaar in the Netherlands, after a hip fracture. He was 92 years old. He was perhaps best known for his prediction of a reservoir of comets residing out past the orbit of Pluto, now known as the Oort Cloud. But he made significant contributions to nearly every field of astronomy. He and Swedish astronomer Bertil Lindblad discovered, in 1927, that our Galaxy rotates. He encouraged others to search ancient astronomical records for evidence of supernovae, establishing the link between the Crab Nebula and the supernova explosion recorded by the Chinese in 1054 A.D. He was an early proponent of radio astronomy, recognizing its enormous potential for astronomical research. He was Director of Leiden Observatory from 1945 until his retirement in 1970 and President of the International Astronomical Union from 1958 to 1961.

In 1942, Oort became one of the youngest recipients of the Catherine Wolfe Bruce Medal of the Astronomical Society of the Pacific for a lifetime of outstanding achievement in astronomy (Oort, Eddington, and Chandrasekhar were all awarded the Bruce Medal in the 42nd year of their life). This past year, he became the oldest (at 92) contributor to *Mercury* magazine (Mar/Apr 1992) with an article on activity in the center of galaxies, the focus of his most recent research.

almanacs. By 1984 even Brown's theory was superseded, as an electronic computer at the Jet Propulsion Lab began directly integrating the equations of motion with a speed unimaginable in Brown's day. (In 1948, when an electronic computer was first used with Brown's tables, it led to the discovery that Brown had included one term twice.)

Brown's collaborators and Ph.D. students, Henry Hedrick and Wallace J. Eckert, were pioneers in the use of mechanical computers for astronomical computations. The latter[4] headed the Watson Astronomical Computing Bureau, set up by IBM at Columbia University expressly to do scientific computations, well into the era of electronic computers. Brown took an interest in their work, even designing a punched card machine of his own, but he continued to hand crank a mechanical computer after others had switched to desktop electric machines.

Like his predecessor Hill, Brown never married. (His sister, who kept house for him, was said to have "succeeded in utterly spoiling him.") But while Hill was practically a hermit, Brown loved to travel and socialize, once saying, "There is perhaps no one who can feel the need of the group more keenly than he who has worked on a problem alone for much of his life and who has had little opportunity for intercommunication with the few others in his own line except the meager stimulus afforded by a few printed pages appearing at rare intervals."

He was long active in the American Association of Variable Star Observers. Dorrit Hoffleit, who remembers Brown as "a kindly soul," writes, "I find it interesting that a man who solicits amateur help is then awarded an honorary membership and, for a while, the presidency of the AAVSO just because he could get people to work for him *gratis*." She recalls that the amateurs "were delighted to observe [lunar] occultations for him and reduce observations." Brown also presided over the American Astronomical Society, and he helped George Hale organize American scientific talent for the first world war during his term as president of the American Mathematical Society.

Brown's working routine was unusual: "He would retire rather early in the evening and as a consequence would awaken usually from three o'clock to five o'clock in the morning. Having fortified himself with a number of cigarettes and a cup of strong coffee from a thermos bottle, he would then set to work in earnest without leaving his bed. At nine o'clock he would get up and have his breakfast. Unless he had something especially exciting on hand, he would not return to mathematical work until the next morning, devoting the intervening time to correspondence, teaching and other similar duties."[5]

He read the proofs of his last paper just days before his death. Titled, "The Equations of the Motion of the Moon," it reported that with a new method he had just developed and the use of mechanical computers, "we have been able in a year or two to test and extend calculations which took me nearly twenty years to carry out with the old fashioned methods." ■

4. No relation to J. Presper Eckert, Jr., one of the first to build a modern computer.

5. Frank Schlesinger and Dirk Brouwer, *Biographical Memoirs of the National Academy of Sciences*, volume 21, page 243 (1940). [Both authors worked with Brown at Yale, and both became Bruce medalists.]

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