# The inventor of modern science

**James Bradley laid the foundations of modern science in his aunt's attic. His impressively precise astronomical measurements gave birth to experimental physics as we know it. The first in our series of millennium essays.**

**Freeman J. Dyson**

Modern science began in 1729, when it became based on measurements of high precision. This makes James Bradley, who did the first high-precision measurements, the inventor of modern science. He was the first to understand that accurate measurement requires meticulous monitoring and control of possible sources of error. He was the first to record temperature and barometric pressure whenever he made an observation.

In 1729, Newton had been dead for two years. Only 120 years had passed since Galileo's little telescope had first been pointed at Jupiter and its satellites. Bradley had the good luck to have a widowed aunt who owned the house where she lived in Wanstead, east London. The house had a high roof, and the aunt allowed him to cut a hole in her roof and use the upper part of the house as an observatory. Her husband had also been a devotee of astronomy, so she was used to this sort of madness. Under the hole, Bradley suspended a slender three-inch refracting telescope, with a brass circular arc along which the eyepiece of the telescope could be moved with a micrometer screw.

The eyepiece was focused simultaneously on a star overhead and on a fine crosswire. Bradley could move the star exactly onto the crosswire with the micrometer screw, and then read off the angle on the brass arc. At one place on the arc there was a notch leaving space for a vertical plumb-line made of wire with one hundredth of an inch diameter. We must assume that he had his aunt well trained so that she did not slam doors while observations were in progress.

Using his plumb-line and his micrometer screw, Bradley was able to measure the angle between a star and the local vertical with six-figure accuracy, with an error of one or two parts per million. He was the first person to measure anything with six-figure accuracy. He measured angles a hundred times more accurately than the astronomers of Newton's time. That was how he discovered aberration.

Aberration is the displacement of the image of a star in the sky due to the speed of the Earth in its orbit around the Sun. Bradley found that all the stars moved in elliptical paths in the sky, coming back to their original positions after a year. His discovery was acclaimed, not only by astronomers but by the educated public all over Europe, as the first direct demonstration that the Copernican view of the Universe was right. The elliptical motions of the stars in the sky are visual proof that the Earth is moving around the Sun. If the Earth were stationary with the Sun moving around it, aberration could not occur. The displacement in angle is equal to the Earth's velocity divided by the velocity of light. The magnitude of the observed displacements, when compared with the known orbital speed of the Earth, gave the first accurate determination of the velocity of light. Bradley's value for the velocity of light is within one per cent of the modern value.

HULTON GETTY

CORBIS / BETTMANN

**Aberration becomes the norm: Bradley's careful measurements proved that the Earth orbits the Sun, and established the now traditional working methods of science.**

Bradley did not have students in the modern style, but he had assistants, young men whom he trained in precision measurement and calculation. One of his assistants was Charles Mason, who afterwards achieved immortality as surveyor of the Mason–Dixon line separating Maryland from Pennsylvania. The line ran for 233 miles along the parallel of latitude 39° 43′, across land claimed by greedy landowners on both sides. It was important to stake out the line on the ground with astronomical precision. It was important that Mason knew about the disturbing effects of aberration on measurements of latitude. If aberration had not been taken into account, the line might have deviated from its proper position by as much as half a mile north or south, and the American Civil War might have started 100 years earlier than it did.

The influence of Bradley extended far beyond astronomy. The revolution that he started by insisting on six-figure accuracy spread to other countries and to other sciences. A succession of great mathematicians, from Laplace to Gauss and Poincaré, created the new science of analytical dynamics to impose a coherent intellectual order on the precisely observed celestial motions. One hundred and fifty years after Bradley, Albert Michelson and Edward Morley attempted to measure the second-order aberration of light caused by the Earth's motion through the ether, and by their negative result led the way to the theory of relativity.

Finally, after 200 years, the tradition of six-figure accuracy begun by Bradley led to the modern flowering of experimental physics, with Isidor Rabi's molecular beam apparatus probing the resonances of atoms as precisely as Bradley's micrometer probed the motions of the stars. □

*Freeman J. Dyson is at the Institute for Advanced Study, Princeton, New Jersey 08540, USA.*