COSMIC BACKGROUND BY MARCIA BARTUSIAK

Ye Olde Black Hole

An eighteenth-century theorist was just too far ahead of his time.

Born on Christmas day in 1724, the Englishman John Michell was a geologist, astronomer, mathematician, and theorist who regularly hobnobbed with the greats of the Royal Society of London, such men as Henry Cavendish, Joseph Priestley, and even the Society's American fellow Benjamin Franklin (during the diplomat's two long stays in London). The claim could be made, science historian Russell McCormmach has written, that Michell was "the most inventive of the eighteenth-century natural philosophers." Yet until recently, if he was remembered at all, it was for his suggestion, in 1760, that earthquakes propagate as elastic waves through the Earth's crust. That earned Michell the title "father of modern seismology." A torsion balance he invented was later used by Cavendish to weigh the entire Earth.

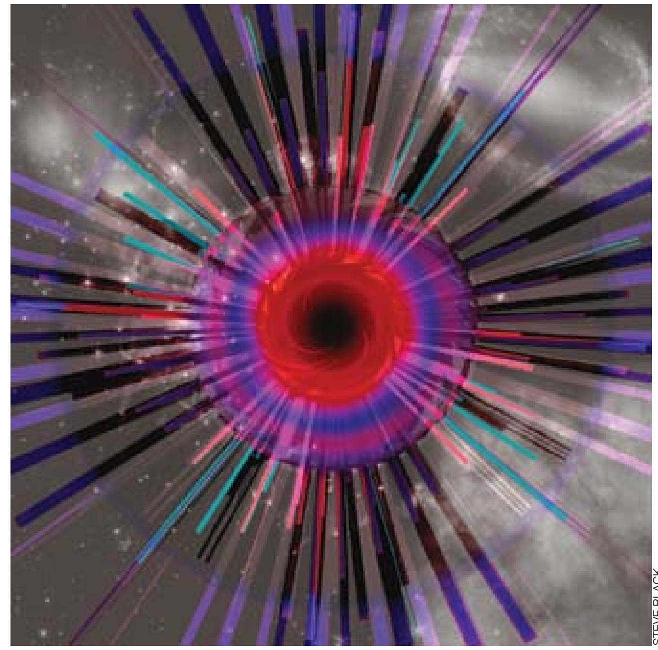
Otherwise Michell was largely forgotten, because he had the unfortunate habit of burying original insights—such as the inverse-square law of magnetic force—in journal papers that focused on inferior research. Some of his greatest ideas were casually mentioned in asides or footnotes. Consequently, long-lasting fame eluded him.

Michell began his scientific investigations at Queens' College in Cambridge. Son of an Anglican rector, he entered Queens' in 1742 at the age of seventeen and after graduation remained there to teach for many years, eventually becoming a rector as well. A contemporary described him as a "short Man, of a black Complexion, and fat. . . . He was esteemed a very ingenious Man, and an excellent Philosopher."

But by 1763, ready to marry, Michell decided to devote himself to the church. He ultimately settled in the village of Thornhill in West Yorkshire, where he served as a clergyman until his death in 1793 at the age of sixty-eight. Yet, over those years with the Church of England, the reverend continued to indulge his wide-ranging curiosity. He had a nose for interesting questions and was willing to stick his neck out in speculation, though always grounded in his first-rate mathematical skills. One of Michell's more intriguing conjectures at this time, right when Great Britain was recovering from its war with colonial America, was imagining what today we would call a black hole.

This idea grew out of an earlier prediction that Michell had made. Astronomers in the eighteenth century were starting to see more and more double stars as they scanned the celestial sky with their ever-improving telescopes. The common wisdom of the time declared that such stars were actually at varying distances from Earth and closely aligned in the sky by chance alone—that it was just an illusion that they were connected in any way. But, with remarkable insight, Michell argued that nearly all those doubles had to be gravitationally bound together.

He was suggesting that some stars exist in pairs, a completely novel notion. In a groundbreaking paper published in 1767, he worked out the high probability that, given how



STEVE BLACK

most other stars were arranged in the sky, the twin stars were physically near one another—"the odds against the contrary opinion," he stressed, "being many million millions to one." (As usual, he displayed the results in a footnote.) In carrying out this calculation, Michell was the first person to add statistics to astronomy's repertoire of mathematical tools. The paper was "arguably the most innovative and perceptive contribution to stellar astronomy . . . in the eighteenth century," according to the astronomy historian Michael Hoskin.

At the same time, Michell recognized that double stars would be quite handy for learning lots of good things about the properties of stars—how bright they are, how much they weigh, how vast is their girth. Two stars orbiting each other were the perfect laboratory for testing out Newton's laws of gravity from afar and arriving at answers. Yet, nearly all astronomers in his day weren't concerned with such questions. They were too busy discovering new moons or tracking the motions of the planets with exquisite precision. To them, the stars were merely a convenient backdrop for their solar-system measurements.

The British astronomer William Herschel, a friend of Michell's, was the rare exception, and within a dozen years of Michell's paper on double stars, he began monitoring and cataloging the stars positioned close together in the sky. Encouraged by Herschel's growing data bank, Michell decided to extend his ideas on double stars in a paper with the marathonic title "On the Means of discovering the Distance, Magnitude, &c. of the Fixed Stars, in consequence of the Diminution of the Velocity of their Light, in case such a Diminution should be found to take place in any of them, and such other Data should be procured from Observations, as would be farther necessary for that Purpose." It was in this work that Michell hinted at the possibility of a black hole—or at least his eighteenth-century, Newtonian version of one.

The eminent Henry Cavendish, discoverer of hydrogen and its connection to water, read Michell's paper before the Royal Society over three successive meetings in December 1783 and January 1784. (It was then published in the Royal Society's *Philosophical Transactions,* taking up twenty-three pages in print.) Michell was devoted to the Society and at least once a year traveled the arduous 200 miles from Yorkshire to London to either attend its meetings or meet with Society friends. But for those December and January meetings the reverend inexplicably stayed home. It could have been ill health, but some historians have speculated that Michell recognized the daring nature of his paper and thought it would be more readily accepted if his close friend and highly respected colleague presented it to the Society.

The radical technique that Michell was proposing to apply to study the stars involved the speed of light. If astronomers closely monitored the two stars in a binary system moving around each other over the years, noted Michell, they could calculate the masses of the stars. It was a basic application of Newton's laws of gravity. And if the motions of paired stars were affected by each other's gravitation, suggested Michell, light should also be affected. This was an era when light was assumed to be made up of "corpuscles," swarms of particles—largely because the great Newton had championed that idea.

Now imagine those particles journeying off a star and out into space. They, too, would be attracted by gravity, just as matter is, assumed Michell. The more sizable the star, the stronger the gravitational hold upon the light, slowing down its speed. There would be a "diminution of the velocity of [the stars'] light," as the title of his paper announced. Measure the velocity of a beam of starlight entering a telescope and, *voilà,* you obtain a means of weighing the star.

This is where the "black hole" possibility arises: Michell took this scenario to the extreme and estimated when the mass of the star would be so great that "all light . . . would be made to return towards it, by its own proper gravity"—like a spray of water shooting up from a fountain, reaching a maximum height, and then plunging back down to the bowl. With not one radiant corpuscle escaping from the star, it would remain forever invisible, like a dark pinpoint in the sky. According to Michell's calculations, this transformation would occur when the star was about 500 times wider than our Sun and just as dense throughout. In our solar system, such a star would extend past the orbit of Mars.

In 1796, in the midst of the French revolution, the mathematician Pierre-Simon de Laplace independently arrived at a similar conclusion. He briefly mentioned these *corps obscurs,* or hidden bodies, in his famous *Exposition du Système du Monde* (*The System of the World*), essentially a handbook on the cosmology of his day.

But did it even make sense to predict the existence of stars that could never be seen? Laplace may have had second thoughts, or simply a loss of interest. In subsequent editions of *Système du Monde,* which he published up until his death in 1827, he expunged his invisible-star speculation and never referred to it again. Michell, on the other hand, displayed greater ingenuity by suggesting a way to "see" such invisible stars. If one of them revolved around a luminous star, he noted, its gravitational effect upon the bright star's motions would be noticeable. It's the very way that astronomers today track down black holes.

In the end, though, Michell and Laplace were getting ahead of themselves, contemplating problems before the physics was in place to answer them. They didn't yet realize that supergiant stars have far lower densities than the ones they envisioned. They also never considered that the same invisibility effect could happen if a star were smaller but very, very dense. They just assumed that all stars shared the same density as the Sun or Earth. Could anything be more dense than the elements found on Earth? It seemed unthinkable in the late eighteenth century.

Both Michell and Laplace were working with an inadequate law of gravity and the wrong theory of light. They didn't yet know that light never slows down in empty space. Proving the existence of such dark stars required more advanced theories of light, gravity, and matter. The modern conception of the black hole would not emerge for nearly a century. It had to wait for the entrance of the twentieth century's most inventive natural philosopher, Albert Einstein.

Marcia Bartusiak is executive director of the MIT Graduate Program in Science Writing and the award-winning author of five books on astronomy and astrophysics, most recently of The Day We Found the Universe *(Pantheon Books, 2009).*