THE MAN WHO INVENTED BLACK HOLES

His work emerges out of the dark after two centuries

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Black holes are at present enjoying a certain vogue in astrophysics; scarcely a week passes in which they are not invoked to account for some set of astronomical observations. The basic definition of a black hole is that it is a region of space towards which the gravitational attraction is so great that not even light can escape. This idea is not a difficult one, at least superficially, although is does lead into various conceptual difficulties which can only be resolved properly by applying Einstein's theory of general relativity (*New Scientist*, vol 81, p 756).

The idea that if the escape velocity of a body (the velocity a projectile needs to overcome the body's gravitational attraction) exceeds the velocity of light then the body will be effectively invisible or "black" is so simple that it prompts the question as to who first thought of it. Until recently I had believed, in common with most scientists studying gravity, that the answer to this was Pierre Laplace, the celebrated French mathematical astronomer. In the first and second editions of his book *Exposition du Systeme du Monde* published in 1796 and 1799, he stated that a body whose diameter exceeds 250 times that of the Sun and with the same density as that of the Earth would appear invisible. In 1799 he published a proof of the result in a German astronomical journal – a translation of which is included in the advanced textbook on general relativity by George Ellis and Stephen Hawking. However, it now appears that Laplace was preceded by some 13 years by a much less well known English Physicist – John Michell. This fact has recently been pointed out by Stanley Jaki in a footnote in an article on another early work on light and gravitation, by Joanne von Soldner, which is published in the current edition of *Foundations of Physics*.

Royal Society paper

Michell's prediction of the existence of what we call black holes was made in a paper read before the Royal Society on 27 November 1783 and which is to be found in the *Philisophical Transactions of the Royal Society* vol 74 p 35, published in 1784. Michell's paper is quite a considerable one – much larger and more detailed than that of Laplace. He was not primarily concerned with black holes, but with the problem of determining the sizes of stars, as is indicated by its characteristically lengthy 18th century title: "On the Means of Discovering the Distance, Magnitude etc of the Velocity of Light, in Case of 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 further Necessary for that Purpose."

Michell starts his paper by deducing the amount that the gravity of a star would slow down the journey of an ordinary particle from the surface of a star to Earth, assuming the usual laws of Newtonian mechanics. He then says, "Let us now suppose the particles of light to be attracted in the same manner as all other bodies with which we are acquainted; that is, by forces bearing the same proportion to their *vis inertiae* (or mass), of which there can be no reasonable doubt, gravitation being, as far as we know, or having any reason to believe, an universal law of nature." From this assumption he deduced "... if the semi-diameter of a sphere of the same density as the Sun were to exceed that of the Sun in the proportion of 500 to 1, a body falling from an infinite height towards it, would have acquired at its surface greater velocity than that of light, and consequently supposing light to be attracted by the same force in proportion to its *vis inertiae*, with other bodies, all light emitted from such a body would be made to return towards it by its own proper gravity".

He goes on to argue that less massive bodies would merely produce light moving more slowly than usual, and to design an ingenious prism experiment for comparing the velocities of light from two separate stars which form part of a binary system revolving about each other. Later he says "If there should really exist in nature any bodies whose density is not less than that of the Sun, and whose diameters are more than 500 times the diameter of the Sun, since their light could not arrive at us; or if there should exist any other bodies of a somewhat smaller size which are not naturally luminous; of the existence of bodies under either of these circumstances, we could have no information from sight; yet, if any luminous bodies infer their existence of the central ones with some degree of probability, as this might afford a clue to some of the apparent irregularities of the revolving bodies, which would not be easily explicable on any other hypothesis; but as the consequences of such a supposition are very obvious, I shall not prosecute them any further".

From these quotations it is clear that Michell in 1783 understood many of the basic principles of black hole physics which are in daily use almost 200 years later. In some respects he is in error. We now know that the prism experiment he proposed and which was actually carried out by the astronomer Nevil Maskelyne was doomed to failure. Einstein's theory is built on the assumption that light from all sources has the same velocity when it reaches us. The reason that it can be "slowed down" is because of the distortion which gravity produces in space and time. We also know that light has many wavelike properties which cannot be accounted for by the Newtonian particle theory that Michell used. Indeed, the probable reason that Michell's speculations were largely forgotten in the 19th century was that the Newtonian particle theory of light was completely overthrown by the wave theory of Thomas Young (1801), and not until the development of quantum theory did the concept of a particle of light, or photon, become scientifically respectable again.

Michell himself made other important contributions to physics; he was the first person to enunciate clearly the inverse square law for magnetic forces, and it was he and not Henry Cavendish who first suggested what is now inaccurately referred to as the "Cavendish experiment". In this experiment the tiny force of gravitational attraction between two lead balls is measured using a delicate "torsion balance". Michell attempted the measurement himself but ill health and his death prevented a successful conclusion. Later, Cavendish was able to achieve what had eluded Michell, and in his classic paper on the subject he properly acknowledges Michell, a personal friend.

Michell was highly regarded in his own day but since then his reputation has fallen. His work illustrates the power of simple physical reasoning to elucidate the essential features of a highly complicated subject and to extract from it important predictions. These qualities are as important today as they were 200 years ago. In my view he deserves more credit than he has so far been given.