JHA, x (1979), 42–43

NOTE

JOHN MICHELL AND BLACK HOLES

It has been common in recent discussions of black holes to cite the work of Laplace in 1796 and 1799 as the first example of any detailed investigation of the phenomenon of the capture of light by a massive star.[1] In his *Exposition du système du monde* (1796) Laplace states that any star of the same density as the Sun and with a diameter 250 times greater will capture all the light it radiates. In 1799 he produced a quantitative calculation to prove this claim.[2] But as early as the 1770s John Michell, rector of Thornhill in Yorkshire and one of the most inventive astronomers of the eighteenth century, was speculating about the attraction of light by gravity, and in 1783 he produced a paper which includes a much earlier investigation than that of Laplace. This paper, printed in the *Philosophical transactions* in 1784, has been discussed in some detail by Russell McCormmach, but this was before the growth in interest in black holes amongst cosmologists.[3] John Michell's originality has therefore hitherto gone unnoticed.

In his *History and present state of discoveries relating to vision* . . . (1772), Joseph Priestley quoted Michell's result that the force between light particles is $1{\cdot}9 \times 10^{19}$ times more than the force of gravity at the Earth's surface, and printed Michell's speculations on the retardation of light emitted from the Sun.[4] This is one of the earliest references to Michell's work on the gravity of the particles of light, and Michell mentions this in the letter to Cavendish which prefaces the paper of 1783. In this paper Michell attempts to show that the quantity of light emitted by a star is determined by its mass, and the brightness of a star is related to its area and hence its density. The comparison of brightness as a means of determining the distance of a star could therefore be replaced by an estimate of its mass. The mass could be determined by measuring the escape velocity from the star, and hence by measuring the diminution in the velocity of light from the star because of its gravitational pull.

In the course of this argument Michell determined the escape velocity from the Sun, and calculated it to be 497 times smaller than the velocity of light. Hence, Michell argued, any star with a radius 497 times larger than that of the Sun, assuming it to have the same density, will trap all the light it emits.

> If the semidiameter of a sphaere of the same density with 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 a 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.[5]

These bodies would forever remain unobservable, except, Michell points out, by their effect on their satellites:

> . . . of the existence of bodies . . . under these circumstances we could have no information from sight, yet, if any other luminous bodies should happen to revolve about them we might still perhaps from the motions of these

> revolving bodies infer the 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. . . .[6]

Michell's suggestions about the gravitation of light and its use in determining the mass and hence distance of stars were passed on by Cavendish to Maskelyne and to William Herschel. Herschel had already corresponded with Michell three years before about the construction of lenses and telescopes. Herschel now used a modified form of the method Michell had suggested to measure the retardation, but was unable to detect any effect on the velocity of starlight. Michell suggested to Cavendish that this might be because no star was heavy enough.[7] In 1791 Herschel took up the theme of the capture of starlight by gravity in his paper on nebulae: once again the faith in a particulate theory of light led to the belief in its susceptibility to gravity.[8]

> . . . in the immense range of its course [light] must pass through innumerable obstacles to its rectilinear progression. Not to mention the great counteraction of the united attractive force of whole sidereal systems, which must be continually exerting their power upon the particles while they are endeavouring to fly off.

As Herschel argued, the nebulous matter might well be composed by the gravitational agglomeration of light, and hence true nebulae were evidence for the reality of the effect Michell had discussed. So both Michell and Herschel had examined the capture of light by gravity before Laplace's work of the late 1790s.

University of Cambridge SIMON SCHAFFER

REFERENCES

1. See S. W. Hawking and G. F. R. Ellis, *The large scale structure of space-time* (Cambridge, 1973), 365–8.
2. P. S. Laplace, *Exposition du système du monde* (Paris, 1796), ii, 305, and in *Allgemeine geographische Ephemeriden* (1799).
3. Michell's paper is "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 Data should be procured from Observations, as would be farther necessary for that Purpose", *Philosophical transactions*, lxxiv (1784), 35–57, read 27 November 1783. See C. L. Hardin, "The Scientific Work of John Michell", *Annals of science*, xxii (1966), 27–47 and R. McCormmach, "John Michell and Henry Cavendish: Weighing the Stars", *British journal for the history of science*, iv (1968–69), 126–55.
4. J. Priestley, *The history and present state of discoveries relating to vision, light and colour* (London, 1772), 387–90 and 787–91. There was considerable discussion of the wasting away of the Sun by the loss of light: Priestley used Michell's work to show that this loss was less than two grains per day.
5. Michell, *op. cit.*, 42.
6. Michell, *op. cit.*, 50.
7. McCormmach, "John Michell and Henry Cavendish", 148, quoting letters from Cavendish to Michell, 12 August 1783 and from Michell to Cavendish, 20 April 1784. For Michell's relations with Herschel see C. A. Lubbock, *The Herschel chronicle* (Cambridge, 1933), 91.
8. William Herschel, "On Nebulous Stars, properly so called", *Philosophical transactions*, lxxxi (1791), 71–88, p. 88.