On the Existence of Black Holes.

Jeremy Dunning-Davies,
Institute for Theoretical Physics and Advanced Mathematics (IFM) Einstein-Galilei,
Via Santa Gonda,
14 – 59100 Prato,
Italy
and
Institute for Basic Research,
Palm Harbor, Florida, U.S.A.
j.dunning-davies@hull.ac.uk

Abstract.

Black holes are favourite objects for so many different groups of people to discuss. Many physicists discuss them quite seriously, while their possible existence must bring great joy to writers of science fiction. However, what is the theoretical background for their existence and what precisely is meant by the term 'black hole'?

Introduction.

For some time now, the scientific literature has been scattered liberally with numerous articles on black holes, including so-called supermassive ones at the centres of galaxies, all tacitly appearing to assume that such objects actually exist. Some have been purely theoretical studies, while others have included claims that such objects have been observed, albeit indirectly. However, what is the true position? Is it actually beyond doubt that theory even predicts the existence of such esoteric objects in our universe? Also, precisely what is meant by the actual term 'black hole'? It is the object of this short note to examine these questions and possibly consider other points related to them as well.

The Beginnings.

It is claimed by some that the idea of a black hole was introduced into physics via Newtonian mechanics by John Michell in 1784 [1]. However, what Michell actually did was to examine the situation where the escape speed from a massive body becomes equal to, or greater than, the speed of light. A true escape speed is such that any body possessing a lower speed may escape from the surface of the more massive body but, because it hasn't achieved escape speed, must eventually fall back to the surface of the said massive body. Hence, for a massive body which is such that its escape speed is equal to, or greater than, the speed of light, even light may leave the surface of that body but it must eventually return to that surface. This means that an appropriately positioned observer would be able to see the massive body but another observer, positioned at a greater distance, would not. Such a body would not, therefore, be totally black, as has been pointed out by McVittie [2], but might be termed more correctly a dark body rather than a black hole. The crucial point here is that it is not, strictly speaking, correct to claim that a black hole is merely a massive body with an escape speed equal to, or greater than, the speed of light. In fact, only the notion of a dark body, as discussed here, is derivable from Newtonian mechanics; to go further, results associated with Einstein's relativity theories must be considered.

Modern Developments.

Towards the middle of the last century, the present idea of a black hole appeared and, as will be seen, it is a totally different concept from the dark body of Michell. The present day notion of a black hole occurs as a consequence of a mathematical singularity appearing in the popular form of the Schwarzschild solution to Einstein's field equations of general relativity for the case of a spherically symmetric mass point. This material appears in most textbooks on general relativity and cosmology [3]. Normally, this solution is stated as

$$ds^2 = \left\{1 - \frac{2Gm}{rc^2}\right\} c^2 dt^2 - \left\{1 - \frac{2Gm}{rc^2}\right\}^{-1} dr^2 - r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right)$$

where G is the universal constant of gravitation and c the speed of light. Here r, θ, and ϕ appear to be normal polar co-ordinates.

In the above expression, a mathematical singularity is seen to occur when $r = 0$, as might be expected for polar co-ordinates. However, due to the form of the coefficient of dr^2, it follows that a second mathematical singularity occurs when $rc^2 = 2Gm$. The first singularity is regularly dismissed as being merely a property of polar co-ordinates and, therefore, of no physical significance. The second singularity, however, tends to have a physical interpretation attributed to it - namely that it is said to indicate the existence of a black hole. Somewhat ironically, as will be seen later, this is referred to as a Schwarzschild black hole. If this interpretation were valid, it would imply that, for an object of mass m and event horizon radius r to be a black hole, it would need to satisfy the inequality

$$m/r \geq c^2/2G = 6.7 \times 10^{26} \text{ kg/m}.$$

It is of interest to note that, for Michell's dark body, the ratio of mass to actual radius, rather than radius of the event horizon, formally gives exactly the same result [1]. However, in the case of a Michell dark body, the inequality is linked irrevocably with the idea of a traditional escape speed; in the modern notion of a black hole, the idea of an escape speed plays no part.

As stated above, many modern texts quote the equation given above as the Schwarzschild solution of the Einstein field equations, but is this so? Recently, an English translation of Schwarzschild's article of 1916 [4] has appeared and this has made the original work accessible to many more people and enables the above question to be raised by more people. Schwarzschild is easily seen to present his solution in the form

$$ds^2 = (1-\alpha/R)dt^2 - (1-\alpha/R)^{-1}dR^2 - R^2\left(d\theta^2 + \sin^2\theta d\phi^2\right),$$

where $R = (r^3 + \alpha^3)^{1/3}$ and r is the usual polar coordinate. However, in the Michell case, r represents a true radius but that is not the case in the Schwarzschild case as has been carefully explained by Crothers [5].

Hence, Schwarzschild's actual solution does contain a singularity when $R = \alpha$, but R is not the polar co-ordinate. It is clearly seen from above that, when $R = \alpha$, $r = 0$; that is, the singularity actually occurs at the origin of polar co-ordinates, as is usual. Therefore, according to Schwarzschild's own writing there is simply no singularity at $rc^2 = 2Gm$ and so the argument for general relativity predicting the existence of black holes cannot be justified by reference to the so-called Schwarzschild solution and it seems, as pointed out earlier, not a little ironic that non-rotating, uncharged black holes should be called Schwarzschild black holes

The above is merely one objection to the modern theory associated with the notion of black holes. Further serious objections to the popular position on the existence of so-called black holes as seemingly deduced from the claimed Schwarzschild solution to Einstein's field equations may be found in the article by Stephen Crothers where he considers the alleged black hole binary in Nova Scorpii [6]. It might be noted that all the objections, both there and here, are linked with the physical interpretation of mathematical results and this highlights, once again, the true role of mathematics in theoretical studies in physics – the mathematics is purely a tool which must always remain subservient to the physics. In this particular instance, a quite specific geometrical model has been defined and deductions via mathematical manipulations have been made, and continue to be made. The problem arises when attempts are made to link all this purely mathematical theory with physical reality. As has been explained by Crothers in the above reference, the fundamental model, which provides the starting point for all the deductions and discussion that has and is taking place, does not provide an accurate representation of what is actually observed.

Further, these days, claims for the identification of black holes appear fairly regularly in the scientific literature. Quite often, the supposed existence of massive black holes is invoked to explain some otherwise puzzling phenomenon. However, so far, on no occasion has the postulated object satisfied the requirement mentioned earlier that, for a black hole, the ratio of the body's mass to its radius - or more specifically in general relativistic language, the radius of its event horizon - must be subject to the restriction

$$m/r \geq 6.7 \times 10^{26} \text{ kg/m}.$$

Also, what some regard as the defining feature of a black hole – its event horizon – has never been positively identified. Now it emerges that the mathematical singularity at the centre of the discussion simply did not appear in Schwarzschild's original solution of Einstein's equations. Obviously mathematics was used by Schwarzschild to find this solution, but it was used meticulously. It was noted carefully that, if a transformation of coordinates for which the determinant of the transformation does not equal unity is used, then the field equations themselves would not remain in an unaltered form. Hence, Schwarzschild adopted a transformation for which the value of the said determinant was one and went on to derive an exact - not approximate - solution to the equations. Also, Einstein himself proved that the singularity appearing in the popular form of the Schwarzschild solution has no physical significance [7]. In all that Schwarzschild and Einstein did on this topic, the mathematics was a tool to help them achieve what they wanted. At no point was physical reality modified to fit a mathematical conclusion. This is the way things should be and provides an object lesson to many; mathematics is a tool in theoretical physics as elsewhere and, as such, must be subservient to the physics. Where then does that leave the modern notion of a black hole? Considerations such as those above undoubtedly raise major questions about the basis of much modern work, especially with claims of identifying black holes.

Concluding comments.

The obvious conclusion from all the above is that there is massive doubt over much that is popularly supposed about these objects referred to as black holes. In fact, even their actual existence is called into question. No object has, as yet, been identified as being a black hole beyond reasonable doubt. All objects constantly termed black holes – whether they be of the supermassive variety or not – have only been identified indirectly or simply had their existence postulated to explain some other phenomenon; the crucial inequality mentioned has not been satisfied and an event horizon has not been found. It might be wondered, therefore, where this leaves modern cosmology? The answer might appear somewhat surprising.

If, for one moment, all minds could be cleared of such notions as black holes, dark matter, dark energy and dark flow, a new better, deeper understanding of our universe might begin to emerge. In all that has been said here, not one word has been uttered against the idea of a dark body as suggested by Michell all those years ago. Of course, Michell's idea is based on Newtonian mechanics and so, is a body born out of a theory based purely on gravity as the all important force acting. As such though, it is not unreasonable and allows the presence of dense massive bodies at the centres of galaxies. It is, though, a body derived from a rather narrowly based basic theory; that is, one in which the force of gravity is all important. As is well known, gravity is a rather weak force, being roughly thirty-nine orders of magnitude weaker than the electromagnetic force. Again, our Earth and the surrounding Solar System are unusual in that they are not composed primarily of plasma, unlike the vast majority of the Universe. In most areas of the Universe, plasma is the dominant form of material and so, in those vast areas the electromagnetic field must have an important role to play. Plasma is, of course, a form of matter which has been studied extensively in earthbound laboratories and many effects witnessed through high powered telescopes are mirrored in observations made in plasma physics laboratories. This is not the time or place to go into this huge subject in detail but, suffice it to say, a careful examination of the effects of the electromagnetic field offers alternative explanations for many observations in cosmology and can offer actual explanations for many others which continue to perplex cosmologists and astrophysicists hidebound by the dictats of presently accepted theory; for example, there is really no need to postulate the existence of such exotic material as dark matter, dark energy or even dark flow. If the presence of so much plasma in space leads to the existence of so-called Birkeland currents and to plasma pinch effects then, due to the magnitude of the electromagnetic force, these could easily produce results presently explained by such esoteric notions as black holes and dark matter. Many might want to dismiss plasma cosmology out of hand for reasons of their own. However, it is undoubtedly true that, if science is to progress and come nearer unravelling the mysteries of our Universe, minds must open to other approaches and, in the present context, ideas associated with the presence of electric and magnetic fields in space must be explored, always remembering that these entities can be, and have been, examined in laboratories and modelled on computers extensively already.

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