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Black Holes in General Relativity

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Abstract. It is assumed that the singularities which occur in gravitational collapse are not visible from outside but are hidden behind an event horizon. This means that one can still predict the future outside the event horizon. A black hole on a spacelike surface is defined to be a connected component of the region of the surface bounded by the event horizon. As time increase, black holes may merge together but can never bifurcate. A black hole would be expected to settle down to a stationary state. It is shown that a stationary black hole must have topologically spherical boundary and must be axisymmetric if it is rotating. These results together with those of Israel and Carter go most of the way towards establishing the conjecture that any stationary black hole is a Kerr solution. Using this conjecture and the result that the surface area of black holes can never decrease, one can place certain limits on the amount of energy that can be extracted from black holes.

1. Introduction

It has been known for some time that a non-rotating star of more than about two solar masses has no low temperature equilibrium configuration. This means that such a star must undergo catastrophic collapse when it has exhausted its nuclear fuel unless it has managed to eject sufficient matter to reduce its mass to less than twice that of the sun. If the collapse is exactly spherically symmetric, the metric is that of the Schwarzschild solution outside the star and has the following properties (see Fig. 1):

1. The surface of the star will pass inside the Schwarzschild radius $r = 2Gc^{-2}M$. After this has happened there will be closed trapped surfaces [1, 2] around the star. A closed trapped surface is a spacelike 2-surface such that both the future directed families of null geodesics orthogonal to it are converging. In other words, it is in such a strong gravitational field that even the outgoing light from it is dragged inwards.

2. There is a space-time singularity.

3. The singularity is not visible to observers who remain outside the Schwarzschild radius. This means that the breakdown of our present physical theory which one expects to occur at a singularity cannot affect