ABOUT BLACK HOLES WITHOUT TRAPPING INTERIOR

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ABSTRACT
Physical arguments related with the existence of black holes solutions having a nontrapping interior are discussed. Massive scalar fields interacting with gravity are considered. Interior asymptotic solutions showing a scalar field approaching a constant value at the horizon are given. It is argued that the coupled Einstein-Klein-Gordon equations can be satisfied in the sense of the generalized functions after removing a particular regularization designed for matching the interior solution with an external Schwartzschild spacetime. The scalar field appears as just avoiding the appearance of closed trapped surfaces while coming from the exterior region. It also follows that the usual space integral over T_0^0 in the internal region just gives the total proper mass associated to the external Schwartzschild solution, as it should be expected.

1. RESUME

The questions about the final states of collapsing massive stars is a central issue in Astrophysics. Black holes are expected to be the ultimate configurations of stars being merely twenty times more massive than the Sun [1]. The general point of view asserts that after the collapse a central singularity develops which is surrounded by an interior region being causally isolated from outside [2].

That is the structure shown by all the known black hole solutions, and which also is strongly suggested by the so called singularity theorems [3]. It is a fact that in all the standard solutions, it is possible to find trapped surfaces at arbitrarily near distances from the horizon from the inside. However, it is not evident that all the physical solutions should have such a behavior.

The aim of this work is to discuss physical considerations related with the existence of black hole solutions having a "normal" interior space-time without closed ttrapped surfaces [3]. The Lagrangian system seeming to allow configurations being of interest in this sense corresponds to the massive scalar field interacting with gravity. Here we will consider a solution being spherically symmetric. It shows a scalar field tending to a constant at some "assumed" horizon in such a way that this horizon can be approached from the interior.

The plan of the work goes as follows.

In first place, a regular asymptotic solution of the Einstein and Klein-Gordon equations is obtained in the neighborhood of the origin and numerically extended to a probable horizon at some radius ρ_0. The solution has a scalar field which increases up to a finite value at ρ_0. The asymptotic field configuration was also discussed in the related work [4] in the preparation of which we started to investigate the problems addressed here.

The analytic behavior corresponding to the considered numerical solution in the neighborhood of the expected horizon is also determined. Afterwards, the question of matching the Schwartzschild solution at the exterior is considered. For this purpose the singular field configuration consisting of the considered solution art the interior and the Schwartzschild one at the exterior, is regularized. The scalar field is assumed as vanishing in the outside zone in accordance with the no-hair theorems. Therefore, the scalar field shows a rapid variation near the horizon. The inverse of the radial component of the metric tensor near the horizon tend to vanish on both sides. This property allows to design a regularization which can smooth out the strong singularities of the scalar field derivative in the kinetic energy terms of the Einstein equations. Effectively, after properly selecting the regularization for the three fields involved, it can be argued that they solve Einstein-Klein-Gordon equations in the sense of the generalized functions.

It also follows that the marching conditions fully determine all the parameters determining the starting asymptotic solution in terms of the total black hole mass.

The possibility for the exchanging of real probe particles across the horizon is also conjectured after remarking that: 1) Any arbitrarily small (but real) probe particle would make a nonvanishing back-reaction on the metric being able to locally disrupt the horizon surface when the particle is sufficiently near it. 2) Outgoing particle trajectories of the Schwartzschild space-time always exist for arbitrarily small but finite distances from the horizon from the outside. 3) If the back-reaction is able to allow a falling from the inside probe particle to pass out just a little, then it could go far away the horizon following an outgoing particle trajectory. This can be so because the particle accumulated sufficient kinetic energy during the falling out at the interior.

In Section 2 the interior solution is discussed. Section 3 is devoted to discuss the matching with the Schwartzschild space-time. Finally in a final section conclusions and possibilities for the continuation of the work are given.

2. CONCLUSIONS

Physical arguments about the possibility for the existence of black holes with non-trapping interior are given. The internal solution consists of an interacting with gravity scalar field which is bounded at the horizon. On the contrary, the derivative of the scalar field diverges ar the border. This interior solution, after extended to the external region with the Schwartzschild space-time, is regularized in the neighborhood of the horizon in a particular way. It allows to show that the external sources which are needed for the regularized fields to solve the equations, tend to vanish in the generalized functions sense after removing the regularization. Thus, the studied configuration suggests an alternative equilibrium limit for the collapse of matter described, not by dust particles, but by continuous scalar field configurations. As all the particles are ultimately described by fields, the possibility for the physical relevance of such solutions seems not out of place. It can be also speculated that a kind of behavior of the wave equations coupled with gravity can exists, in which the formation of trapped surface could be rejected dynamically. These questions will be considered elsewhere.

Finally, we would like to remark on other possibilities for the further continuation of the work. A first task which is imagined consists in to numerically solve time dependent solutions produced by a sudden disappearance of the external sources associated to the regularized fields. Such an study could give information about the stability of the singular solution. The stability would be reflected by a tendency of the time dependent fields to reproduce the singular configuration.

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