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A tale of two dyons

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ABSTRACT

We present a one-parameter family of stationary, asymptotically flat solutions of the Einstein–Maxwell equations with only a mild singularity, which are endowed with mass, angular momentum, a dipole magnetic moment and a quadrupole electric moment. We briefly analyze the structure of this solution, which we interpret as a system of two extreme co-rotating black holes with equal masses and electric charges, and opposite magnetic and gravimagnetic charges, held apart by an electrically charged, magnetized string which also acts as a Dirac–Misner string.

1. Introduction

Stationary asymptotically flat black holes with regular connected event horizons are known to be strongly limited by uniqueness theorems and given in the vacuum case by the Kerr metric, and in the electrovacuum case by the Kerr–Newman solution. In the search for alternatives to this standard black hole scenario, prompted by the coming perspectives to receive high accuracy data from the center of the Galaxy, one is led to relax some basic assumptions, among which one could most safely sacrifice horizon connectedness. Many such solutions of the Einstein–Maxwell equations known in the Weyl–Papapetrou form are nicely reviewed in the Griffiths and Podolsky book [1]. Leaving aside the well-known Israel–Wilson–Perjès and Weyl linear superpositions, these solutions can be roughly classified in two families. One was obtained via soliton generating techniques and consists of non-linear superpositions of aligned black holes possibly endowed with charges and NUT parameters. The other contains solutions generated by other methods, such as the static magnetized Bonnor solution [2], or the one-parameter class of static Zipoy–Voorhees (ZV) [3,4] vacuum solutions, also known as γ-metrics, and their rotating Tomimatsu–Sato (TS) [5] cousins with integer γ, the $\gamma = 1$ TS solution coinciding with the Kerr metric. The physical interpretation of these last solutions is far from trivial, and it was only relatively recently recognized that the Bonnor solution [6] or the TS solution with $\gamma = 2$ (TS2) [7] actually describe black-hole pairs. Both families generically contain naked ring-type curvature singularities, and/or milder conical line singularities (strings), which however can be avoided by imposing external fields [6], at the expense of asymptotic flatness. Here we adopt a tolerant attitude with respect to mild naked singularities and do not reject solutions endowed with novel and very intriguing features for the sake of cosmic censorship. It is worth noting that the possibility of violation of cosmic censorship in gravitational collapse has received more attention recently [8].

In this short note (a more detailed version will be published elsewhere) we wish to draw attention to a new electrovacuum solution obtained some time ago by one of us [9] via an original generating technique which produces a one-parameter family of rotating electrovacuum solutions from a given static vacuum one. Application of this procedure to the static ZV metric generates a rotating solution with a magnetic dipole moment, which is the unique so far known rotating generalization of the ZV metric with non-integer γ, and has the advantage to be free from a naked ring singularity. For $\gamma = 1$ it is again the Kerr metric, while for other integer values of γ it is not the vacuum TS metric, but some new electrovacuum metric. Postponing the case of generic real γ for future publication, we concentrate here on the $\gamma = 2$ version which looks the most interesting physically.

2. The solution

This one-parameter family of rotating solutions was generated from the static $\gamma = 2$ Zipoy–Voorhees (ZV2) vacuum solution in [9]. The Ernst potentials of the rotating solution are $\mathcal{E} =$

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