Cataloging Black Hole Solutions to Einstein’s Theory of General Relativity

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What is the catalogue about?

$R_{\mu \nu} - \frac{1}{2} R g_{\mu \nu} = 8 \pi G T_{\mu \nu}$

Einstein’s General Relativity is the leading theory of space-time and gravity: it is highly nonlinear due to the complicated dependence of $R_{\mu \nu}$ to the metric, $g_{\mu \nu}$. This equation represents a set of 10 nonlinear partial differential equations in 4 independent variables (coordinates). A system this complex cannot be generally integrated, thus exact solutions of Einstein’s equations model gravitating systems and allow for the exploration of the mathematics and physics of the theory. Exact solutions include empty spacetimes, black holes, wormholes, gravitational waves and cosmological models of the universe. The focus of this study include empty spacetimes and black holes.

Why is a catalogue useful?

Many exact solutions to Einstein’s equations are known, but the physics not fully interpreted. Computing the components and verifying solutions to Einstein’s solutions can be very convoluted and time consuming. Verifying even some of the most basic solutions can take days if done by hand and are very prone to mathematical error and even typos if done on a computer program.

Publicly available, accurate files with verified solutions to Einstein’s solutions will provide a useful tool to students and researchers working with the various geometries. The catalogue will streamline the process of investigating the physical interpretations of solutions while also mitigating the risk of introducing coding errors.

The catalogue

The catalogue was developed using the Wolfram Mathematica language and base code provided by the University of Wisconsin[1].

Why Mathematica?

Mathematica was chosen because the language is a very popular programming language that utilizes mathematical symbolic computation employed in academia by students and researchers alike.

Moving forward

Looking ahead, towards the development of the catalogue we plan to add and verify many more solutions[2] to Einstein’s field equations including, but not limited to; Reissner–Nordström, Gödel, Taub–NUT and Kerr–Newman solutions. In addition to verifiable solutions we will also aid in interpreting the physics of exact solutions by developing programs to calculate elements of the geometries such as arclength, energy, geodesics and so on.

References


The catalogue has been published online at https://informationgrsolut.wixsite.com/grsolutions and as of April 8th 2018 has 6 files that correspond to 6 distinct solutions of Einstein’s including 2 flat spacetime solutions and 4 Schwarzschild black hole geometries.