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Riemann Hypothesis, Hypercomputing and Physics of Black Holes

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Abstract
In this paper, we consider the relationship between the theory of hypercomputing and some problems of modern physics, in particular, the theory of black holes.

Keywords: hypercomputing, Malament-Hogarth spaces, black holes, instability of electromagnetic vacuum

Introduction
In recent papers [Zayko, 2021], [Zayko, 2020] it has been shown that the successful proof of the Riemann hypothesis (RH) [Zayko, 2017] is associated with overcoming the so called Turing barrier. There is nothing unexpected in this, since this is not the first example demonstrating the insufficient power of traditional, Turing methods of calculations and proofs. It was previously shown that the proof of Hilbert's tenth problem, first obtained by Yu. Mathiasevich (1993), also requires going beyond the Turing barrier [Kieu, 2003].

This work is devoted to clarifying some aspects of the proof of RH that affect other provisions of modern science. The use of a relativistic Turing machine (MT) as a proof tool allows us to identify some features of the direction known as hypercomputing, or rather its part associated with the so called bifurcative MT and also to identify the connection of the problem under consideration with questions traditional for relativistic cosmology, for example, black hole physics [Earmanm & Norton, 1996].
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Singular structure of Malament-Hogarth spaces (M-H)
The concept of M-H spaces as a relativistic space allowing hypercomputing was first introduced in [Earmanm & Norton, 1993]. The peculiarity of its structure is the presence of singularities S of special type, which can be briefly described as follows: "If an object follows a trajectory that falls into the singularity, its journey takes forever as measured by a clock moving with the object, but external observers perceive it to have taken only a finite amount of time to complete its journey into S." [Stannet, 2006].

The results obtained in [Zayko, 2017] allow us to clarify the properties of the M-H spaces associated with their singular structure, which determines their similarity to the event space in the vicinity of the so-called black holes [Landau & Lifshitz, 1975]. First of all, this concerns the need to overcome the so-called event horizon, which requires stitching solutions of the relativistic equations used in the regions above and below the horizon. In the relativistic theory of black holes, this is achieved, for example, by using the so called Finkelstein transform [Landau&Lifshitz, 1975], or their variants and generalizations. The result is the construction of a complete map of events in the vicinity of the singularity.

However, as shown in [Zayko, 2019], these methods implicitly use the assumption of the stability of the electromagnetic vacuum (EV) under the event horizon (which is essential for the existence of photons and therefore the signal exchange), which, as shown in [Zayko, 2016], does not correspond to reality. In [Zayko, 2017; Zayko, 2019], an alternative variant of crosslinking solutions above and below the horizon is used, based on the fact that, in accordance with the instability of EV under the horizon and the impossibility of propagation of signals-electromagnetic waves in this area, time stops in it, or rather, the concept of time itself is absent. This result is important not only for studying the properties of M-H spaces used for hypercomputing, but also for black hole physics, first of all, and, in a broader sense, for cosmology in general, which widely uses the black hole model for its constructions.

Discussion
First of all, let's deal with the formal-mathematical side of the question. The stitching of solutions discussed above now occurs between regions of different dimensions – 2-dimensional (radial coordinate, time) above the event horizon and 1-dimensional (coordinate only) below it. This procedure can be performed due to the properties of real numbers, allowing, for example, displaying the inside of a square with a side of unit length on its

side [Kantor, 1874]. (For problems with mutual unambiguity and continuity of the display, see [Podnieks, 1992]).

Let's return to the discussion of the physical side of the issue. The notion of the absence (concept) of time under the horizon is not something unexpected and new for modern physics and, moreover, naturally appears in the physics of black holes if all their applications are consistently considered and coordinated. Indeed, cosmologists have repeatedly stated that there is no time before the Big Bang. There is also an analogy between the Big Bang and the so-called white hole, a solution associated with a black hole by the operation of time reversal. Therefore, there is no time in the future of a black hole, just as there is no time in the past of a white hole.

Conclusion

This work will allow us to draw attention to the connection between the theory of hypercomputing and some problems of modern physics, in particular, the theory of black holes. The consideration is based on the proof of the Riemann hypothesis using a relativistic Turing machine. Solving Einstein's equations describing the dynamics of a relativistic Turing machine faces problems typical for the study of black holes in relativistic cosmology. The Malament-Hogarth space in which the action of the Turing machine takes place has an event horizon at the boundary of which partial solutions of relativistic equations of motion have to be stitched together. A successful proof of the Riemann hypothesis is possible if we assume that there is no the conception of coordinate time under the event horizon. These considerations may have great implications for relativistic cosmology as well.

It must be noted that above consideration concerns the blackhole physics that works only in a classical scenario. In a quantum scenario the blackhole properties could drastically change, see for example the fuzzball approach [Bena et al., 2022] and the "hydrogenatom" approach [Corda & Feleppa, 2021].

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