Black Holes and the Nature of Reality[1]

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Abstract: We ask the fundamental question: "What is the nature of reality" and show that the common interpretational assumption of Einstein's Equations representing the curvature of absolute spacetime is logically inconsistent when investigating the event horizon and interiors of black holes (BHs). We contend through philosophical and cosmological arguments and through the introduction of unrecognized paradox that the "field formalism" and its "gravitational field in a flat spacetime background" interpretation of gravity presents a more complete description and a deeper understanding of both the Theory of General Relativity (GR) and the enigmatic nature of reality.

I. Introduction

It is not often the physicist asks questions such as: What is the nature of reality? Difficult and often intractable questions such as this are left for the philosophers and poets, not scientists. However, the investigations of BHs bring to the fore questions of the meaning of existence and non-existence by their very nature[2]. In fact, by working in a domain where no experiment or observations can be conveyed to the outside observer, the physicist has been working only on conviction; on conviction of her theory, of the completeness of her mathematics, and in particular, the interpretation of her theory when researching BHs, their horizons and their interiors. This very sentiment is alluded to by Valerie P. Frolov and Igor D. Novikov in the introduction to their beautifully written, comprehensive textbook, *Black Hole Physics/Basic Concepts and New Developments* where they opine:

"Is there any sense in discussing what happens inside a black hole if there is no way to compare our predictions with observations outside of a black hole or to transfer knowledge to the external observer if we decide to dive into a black hole? Perhaps the general answer to this almost philosophical question lies somewhere outside physics itself."[1]

To their credit this quotation alludes to whether the physics of BH interiors is even a valid scientific question in the Popperian sense, yet, the authors proceed to develop this very subject in several subsequent chapters [2], without any further disclaimer in regards to the physics presented there. Understandably so, since this material is not in contradiction with the consensus of the physics community.

Yet, we must ask ourselves, have physicists taken for granted the physics in the domain of BH interiors, with the exception of perhaps only the BH's singularity? Singularities have always created headaches for physicists when they occur in physics. They represent conditions where physical law breaks down. It has thus been the quest of a theory of quantum gravity (QG) to unify GR and quantum

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[1] Essay written for the FQXI's essay contest: Which of Our Basic Physical Assumptions are Wrong?

[2] See part III of this essay for a deeper investigation of this very topic.

theory (QT) in the hope for a complete explanation of (or more appropriately to explain away) the singularity of BHs as well as the singularity existing at the creation/beginning of our universe.
What if, by relying on fallacious convictions and errant reasoning, we have been lead astray. With BHs being the most investigated objects in the history of the GR, by many of the most preeminent physicists of the last three quarters of a century or more, someone surely would have caught a "flaw in the logic". Perhaps not, if the flaw came primarily via logical arguments of a mostly philosophical nature, rather than through the language of advanced mathematics, the physicists' primary tool.

II. The Fundamental Logical Flaw in the Theory of Black Holes

General Relativity has been the standard theory of gravitation since it replaced Newton's Universal Law of Gravitation in the first quarter of the 20th century. The mathematics for GR is considered to be best represented by the non-Euclidean geometry from which Einstein constructed his famous equation:

$$R_{ik} - \frac{1}{2} g_{ik} R = \frac{8\pi G}{c^4} T_{ik} \qquad (1)$$

The geometry of spacetime is represented by the curvature tensor and metric on the left side of (1); whereas on the right side, the material world of mass-energy is represented by the stress-energy tensor. Einstein thought the left hand side to be beautiful and the right hand side ugly, and spent the remainder of his career trying to make the right hand side more beautiful.[3] In other words, he tried to make the ugliness of the real world more like the beauty of the mathematically perfect. Unfortunately, the real world rarely resembles the perfection of the abstract world, although this unwritten tenet still seems prevalent among many in the physics community, even after the emergence of QT.

Perhaps, the main lesson to be learned from QT is that reality on some fundamental level is incomprehensible. While the success of QT as a theory of prediction is unquestionable, its meaning remains almost completely abstruse and illusive. There exist, at the writing of this essay, a minimum of eighteen common interpretations of QT [4], each with varying degrees of acceptance among the physics community. At least the theory of GR doesn't have a problem with interpretation, it *is* the result of the curvature of spacetime; how the presence of mass, energy and pressure curve spacetime and how objects move along geodesics in a curved spacetime. Or is it? As Kip Thorne explains in the eleventh chapter, entitled "What is Reality?", of his popular book *Black Holes & Time Warps / Einstein's Outrageous Legacy*:

"Is spacetime *really* curved? Isn't it conceivable that spacetime is actually flat, but the clocks and rulers with which we measure it, and we regard as *perfect* in the sense of {*see Box 11.1 in ref [5]*}, are actually rubbery? Might not even the most perfect of clocks slow down or speed up, and the most perfect of rulers shrink or expand, as we move them from point to point and change their orientations? Wouldn't such distortions of our clocks and rulers make a truly flat spacetime appear to be curved?
Yes." [6] - {phrase includes Thorne's emphasis}

He then proceeds to detail the three different *paradigms* associated with GR, in particular with BH physics: the curved spacetime paradigm (CSP) - {this is the common description with which we are most accustomed}, the flat spacetime paradigm (FSP) - {brief pedagogical description given in the Thorne's quote above; refers to a method of using a background spacetime, usually flat. For the "field formalism" mathematical description see for example [7]}, and the membrane paradigm (MP) {see [8] for Thorne's full description of this paradigm}.

For our purposes, we need only to consider that each paradigm incorporates three sets of mathematically formulated laws of physics, each set of laws with their subsequent *conflicting* physical interpretation; for they are completely consistent and interchangeable, "so long as one restricts one's attention to the hole's exterior"[9]. ***This is a crucial error***. For an assumption is made that the CSP is the true nature of reality, when in fact there is no experiment, nor observation, that can be done to distinguish between the three different paradigms, anywhere, but especially on the surface and interior of a BH where they are completely incompatible!

Yet, it is common practice to routinely calculate and discuss spacetime solutions on and interior to a BH's horizon with all of these solutions essentially arriving via the CSP.[3] Is the CSP the true nature of reality? This would be a question strictly for philosophers, if all three paradigms were equivalent in every spacetime domain. The interior and horizon of a BH is a domain in which they do not agree. ***When three equally valid descriptions of nature give inconsistent results on a specific domain and/or its boundary then none of the descriptions can presumed to be true without sufficient reason!***

If one considers GR in the context of the FSP, then, essentially, the LHS of equation (1) becomes poorly defined at the horizon and therefore the geometry must also. Remember, in this paradigm our rulers and clocks are "rubbery" using Thorne's simple, yet appropriate colloquialism. Therefore, the length of our rulers and the rates of the ticking of our clocks *in actually* approach zero[4] as they advance toward the BH's event horizon. It therefore becomes unphysical to suggest that they ever reach or cross the horizon.[5] This picture of reality leaves the horizon and interior undefined. If one considers equation (1) in the context of the CSP, then the RHS of the equation becomes poorly defined (spacetime becomes infinitely curved) at the singularity and therefore the mass-energy becomes poorly defined at the singularity as well. Thus, under the CSP the very center of the BH, i.e. the singularity, remains undefined.[11] There is no sufficient reason why our physical description of mass-energy, and the properties associated with spacetime, shouldn't become poorly defined at the event horizon, as the FSP implies, as apposed to the singularity, other than the FSP has no *immediate explanatory ability for the spacetime found at the horizon and on the BH's interior.*

The accepted practice when considering BH interiors is to declare that the coordinate system becomes pathological at the horizon, and then the horizon and interior is replaced by the solution using an alternative coordinate system of curved spacetime.[12] While alternating between differing coordinate systems to obtain a more complete mathematical solution is an acceptable practice in almost every situation[6], it is unequivocally incorrect when considering that ***the very nature of reality changes with the formalism***. How do we determine if gravity doesn't actually change the nature of our rulers and clocks as apposed to changing the nature of spacetime, even though currently one description may seem rather absurd while the other seems more elegant? This question is a matter for philosophy unless we can determine a compelling physical reason to choose one view over the other without resorting to a possibly incorrect assumption.

If the above argument seems somewhat abstruse, it undoubtably arises from our familiarity with and the intuitive description of gravity as "spacetime being curved by the presence of mass, energy and pressure" and "objects moving along geodesics in a curved spacetime". However the wisdom that can be obtained from both the great theories of the twentieth century, namely GR and QT, is that nature in the realm outside of our common experience is extremely counter-intuitive. The FSP and the CSP work equally well to describe our universe with the exception of BH boundaries, interiors and singularities, i.e. realms which are unavailable for experimentation and from all observations. We cannot confidently declare either framework *universally* acceptable, in every domain, without further support.

One might argue that the CSP is mathematically more complete, in that its description leaves only points of spacetime in question, whereas the FSP leaves entire regions of spacetime in question. This undoubtedly was one of the reasons the CSP was accepted by the pioneers of BH physics. Mathematical completeness, however, is no substitute for experimental or observational verification, both of which are physically impossible by definition in the domain under consideration. So, we must fully reconsider our

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[3] There are various coordinate systems used for this purpose. For examples, see [10]

[4] Assuming our rulers are small with respect to the BH's size in order that tidal effects can be ignored.

[5] While there may be some (not this author) who would argue that clocks may be permitted to run backward, suggesting a form of time travel, it is completely nonsensical to speak of rulers with zero or negative length.

[6] Indeed two coordinate systems are needed in order to cover the entire surface of a simple 2-sphere.

present gravitational worldview to ensure we haven't been mistaken in our approach. After all, the CSP remains incomplete as a scientific framework even after many years of research due to its inability to conquer the breakdown of physical law at gravitational singularities.

In the next two sections, we will strengthen the case for understanding the CSP as an extremely useful, yet flawed framework, and opting, instead for the FSP as the true nature of reality by introducing to a heretofore unrecognized BH paradox; a paradox which only has a clear solution if we are willing to reconsider our current intuitive notions with regards to the nature of gravity.

III. The Catastrophic Gravitational Time Dilation Paradox

One can hardly have an interest in BHs without also having a familiarity with the well-known paradox associated with them, namely the information paradox.[13] While this paradox has been widely debated within the community and its solution may or may not have been adequately addressed by the Principle of BH Complementarity [14], an even more fundamental BH paradox has gone unnoticed as such.

Of the profound conclusions of Einstein's Theory of Relativity, the most profound conclusion may be that time as well as space are *both* dynamical. The rate of one's clocks depends upon local conditions. Nowhere is this better illustrated than for an accelerated observer in the vicinity of a BH. Indeed BHs are ideal laboratories of extreme physics due to their extreme local conditions. As an accelerated observer on a radial path nears a simple ideal BH (non-rotating and with zero electrical charge), she experiences gravitational time dilation represented by the following equation:

$$t = w_f T \quad \text{where} \quad w_f = \frac{1}{\sqrt{1 - \frac{R_c}{R}}}, \quad \text{and} \quad R_c = \frac{2GM_{BH}}{c^2}$$

with t representing time in the accelerated frame (proper time), T representing the time for a static observer outside of the BH's sphere of influence, R_c being the BH's critical radius, and R being the distance from the accelerated observer to the BH's center. Now, as the observer approaches R_c , notice that the ratio of t to T, namely w_f , approaches infinity. In other words as the accelerated observer approaches the event horizon, she observes the evolution of the rest of the universe at an ever increasing rate. She will indeed reach the horizon in a finite period of proper time, but only at the end of time as experienced by the rest of the universe! How is it that any observer is able to cross any boundary, if the observer, the boundary, and every other constituent of the cosmos ceases to exist? Are not accelerated observers, local spacetime structure, and BHs part of the cosmos? How can they exist separately from a universe from which they were created? This perplexing scenario illustrates the Catastrophic Gravitational Time Dilation Paradox, a fundamental contradiction in the very meaning of existence.

Einstein considered the universe to best be described by Minkowski's absolute four dimensional spacetime and the key to understanding gravity being the curvature of this absolute spacetime by mass, energy, and pressure, i.e. conditions present locally to produce a local spacetime structure. *The local spacetime structure was never meant to exist in absentia of the overall absolute spacetime.* Under these circumstances we must reconsider the following question: Can geodesics and locally curved spacetime solutions using coordinates explicitly designed to remove the "Schwarzschild singularity"[12] be considered physically viable when they only exist separate from the overall absolute spacetime?

IV. The Simple Solution to the Catastrophic Gravitational Time Dilation Paradox

The Principle of BH Complementarity was proposed to better understand and solve the BH information paradox. In a nutshell, the Principle of BH Complementarity states that an accelerated observer and indeed all in-falling mass-energy to a BH has a dual existence. The quantum information which embodies the very essence of our in-falling observer is purported to exist both on the stretched horizon and interior to the BH's event horizon with no observer able to view each simultaneously[14]. Yet, this duality was undoubtably proposed to meet the conditions of geodesic continuation across the event horizon, i.e., an artifact of the CSP. This duality is superfluous if we consider the FSP as the true nature of reality.

Likewise, the resolution to the CGTD paradox described above becomes trivial. As the object approaches the event horizon, both its rulers and the rate of the ticking of its clocks asymptotically approach zero. The object, and the geodesic of which the object follows, approaches arbitrarily close to the horizon, constrained by the future evolution of the cosmos and by the quantum nature of the object, itself. Thus, once event horizons have formed, they immediately become boundaries for events occurring on both their exteriors as well as their interiors.

V. The Cosmological Ramifications of the Flat Spacetime Paradigm

In Section II above, we established that the question of whether gravity changes the nature of our rulers and clocks as opposed to changing the nature of spacetime was a matter for philosophy if we couldn't determine a compelling physical reason to choose one over the other. In section III, we were introduced to a new BH paradox, namely the CGTD paradox, and learned in section IV of it's trivial solution if we accept a fundamentally new worldview, that of the FSP. The trivial solution of this paradox is a compelling reason to choose a new philosophy of reality regarding the nature of gravity. Likewise, a new cosmology, initially developed by this author, completes the paradigm.

The HBCS Cosmology[15] describes a model of the universe, beginning with a minimal number of pre-suppositions, in which the cosmos is represented by the geometry of S3 (4-dimensional hypersphere), thus having a naturally occurring intrinsic curvature due to the relationship of cosmic events in cosmic time. Our 3-space at a particular epoch of cosmic time is represented by a hyperspherical surface and cosmic time is represented by the radial dimension of S3 beginning at its center and increasing in the outward direction (see fig.).

Since the universe is expanding, the angle of the null surfaces (light cones) w.r.t. the spacelike surface varies as cosmic time, T varies. In the limit, as $T \rightarrow \infty$, null surfaces across the bulk of the cosmos approach the surface of the hypersphere, and ***are therefore indistinguishable*** from the the definition of the photon sphere [16] associated with the event horizon of a BH! Thus, the HBCS Cosmology covers the spacetime interior of the BH with the geometry of the 3-sphere, not based on a presumption, but ***as a constructive consequence*** of the model. The HBCS Cosmology implies that the interiors of all BHs are best represented by a set of cosmic spacetime hypersurfaces, each hypersurface representing a particular "moment" of cosmic time in the overall evolution of the cosmos and therefore completes the description of spacetime in every domain.

Additionally, the HBCS model is exceedingly compelling since it gives a nascent description of the cosmological and BH singularities in which case the cosmic singularity and the event horizons of the embedded BHs in the particular cosmic spacetime are ultimately equivalent as a transition in a cyclically evolving cosmic time. Event horizons of BHs in the HBCS Cosmology are therefore defined both as the local boundaries of the cosmic spacetime in which they are embedded, and cosmic boundaries (in the infinite future) for the cosmic spacetime hypersurfaces on their interiors. This model also proposes reasonable and elegant alternative hypotheses for the observations that lead to the dark matter hypothesis and the formation of structure in the early universe and throughout its evolution. As a framework that is universally complete in every spacetime domain and encompasses more physical phenomena in a unified manner, the HBCS Cosmology along with FSP worldview , provides a more than viable alternative to the conventional Standard Model of Cosmology ($\Lambda - CDM$ Hot Big Bang model).

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