

Reframing Gravity and Relativity: A Critical Dialogue on Black Holes, Spacetime Curvature, and Quantum Theory

Bernard Lavenda



Reframing Gravity and Relativity: A Critical Dialogue on Black Holes, Spacetime Curvature, and Quantum Theory

Bernard Lavenda



DeepScience

Published, marketed, and distributed by:

Deep Science Publishing USA | UK | India | Turkey Reg. No. MH-33-0523625 www.deepscienceresearch.com editor@deepscienceresearch.com WhatsApp: +91 7977171947

ISBN: 978-93-49910-10-2

E-ISBN: 978-93-49910-81-2

https://doi.org/10.70593/978-93-49910-81-2

Copyright © Bernard Lavenda

Citation: Lavenda, B. (2025). *Reframing Gravity and Relativity: A Critical Dialogue on Black Holes, Spacetime Curvature, and Quantum Theory*. Deep Science Publishing. <u>https://doi.org/10.70593/978-93-49910-81-2</u>

The publishers, authors, and editors are not responsible for errors or omissions, or for any consequences arising from the application of the information presented in this book, and make no warranty, express or implied, regarding the content of this publication. Although the publisher, authors, and editors have made every effort to ensure that the content is not misleading or false, they do not represent or warrant that the information-particularly regarding verification by third parties-has been verified. The publisher is neutral with regard to jurisdictional claims in published maps and institutional affiliations. The authors and publishers have made every effort to contact all copyright holders of the material reproduced in this publication and apologize to anyone we may have been unable to reach. If any copyright material has not been acknowledged, please write to us so we can correct it in a future reprint.

Dedication

To Ethan & Ronit

Contents

Dedication		v
Preface		xi
1	What is Gravity?	1
2	Is Schwarzschild's exterior solution a vacuum solution?	5
3	Gravitational Force or Spacetime Curvature?	11
4	Singularities: Removable & Not	17
5	Where are the Gravitational Stresses in Einstein's Equations?	27
6	Incompatibility between Numerical & General Relativity	31
7	Black Hole Thermodynamics	35
8	At What Speed Does Gravity Travel?	73
9	Existence of Gravitational Waves	93
10	Interfermeters: Large and Small	103
11	Clash between Macroscopic & Quantum Measurements	125
12	Cataclysmic Events & Geodesic Paths	137
13	Gravitational Time Dilation	177
14	GPS & Relativity	185
15	Hyperbolic Space & the Speed of Light	247
16	Relativity as Hyperbolic Geometry of Constant Curvature	261
17	Inflationary Scenario	277

18	The Most (In)famous Equation in Physics	291
19	Are General Relativity & Quantum Field Theory Compatible?	305
20	Juxtaposing Macroscopic & Microscopic Systems	333

Preface

It was Galileo's longing for a mechanical proof of the motion of the earth which misled him into formulating a wrong theory of the tides. The fascinating arguments in the last conversation would hardly have been accepted as proof by Galileo, had his temperament not got the better of him.

The quote is taken from Einstein, in authorized English translation of concerning *Il Dialogo sopra i due massimi sistemi del mondo* (*Dialogue concerning the two chief world systems*), published by Galileo in 1632. Although the Universe has 'expanded' in the four centuries since the book was published, but not its prejudices to scientific reasoning, I decided to borrow the title of the book, and the *deus ex machina* that Galileo sought to present his case.

The book, which was banned a year later after Galileo was found to be "vehemently suspect of heresy" based on the book, was then placed on the *Index of Forbidden Books*, for over two centuries. Such is the power of ignorance and those who wield it.

The book has three protagonists:

- 1. Filippo Salviati, a Florentine nobelman who plays the role of an expert in Copernicus's theory of the solar system, and used as a mouthpiece for Galileo himself,
- 2. Giovanni Sagredo who is neutral, and plays the role of an impartial judge who needs convincing, and
- 3. Simplico, after the Italian *semplice*, as in *mente semplice*, who embodies the conventional wisdom arguments of Ptolemy and Aristole, arguing against the Copernican system.

Simplico represented the Italian philosopher, Cesare Cremonini, who is said to have refused to look through a telescope. Nowadays, he would represent enthusiasts who can't wait to look through a telescope and observe what their scriptures tell them they are seeing.

Sadly to say, after four centuries things haven't changed. Anything that upsets the

apple cart is branded as "fringe" and is banned from publication in the so-called respectable scientific journals, and book publishers.

So it was in this vein that I decided to re-enact Galileo's theatrical dialogue using the nascent AI technology in the form of Copilot. I could, therefore, be assured of getting the party lines on all arguments breached. Yet, I found "him" more open to the criticism and skepticism which I advanced than the illustrious scientific institutions which regurgitate what has become known as "conventional" wisdom.

The idea surfaced when I was replying to Quora's questions. Although I get well over a hundred hits a week, it does not translate into book sales. Maybe it is due to the technical level at which they are written, so I decided to do something any layman can understand with discussion been Copilot and myself. I certainly haven't exhausted all the topics, and if this volume is met with some success, then I can certainly add other volumes.

It is quite ironic how ill-conceived theories that violate physics laws, and the models that they are applied to can confirm numerical results, which, in turn, bolster the theories themselves! The examples we will discuss are the detection of a frequency shift in gravitational redshifts, time dilation, inflationary scenario, pushing the Schwarzschild outer solution into a region that is forbidden, black hole 'thermodynamics' the 'detection' of gravitational waves, and more.

The gravitational redshift comes about by using the speed of light as an absolute constant so that you can switch between frequency and time. What should have been governed by Snell's law becomes the domain of the Doppler effect. Time dilation again comes from treating c as an absolute constant rather than as a scale factor in a non-Euclidean geometry. This shows that hyperbolic geometry of constant negative curvature is really the home of special relativity. The inflationary scenario which is exponential increase in entropy is justified by using Einstein's field equations which are adiabatic. It's like getting something for nothing.

When Schwarzschild derived his solutions from the Einstein condition of 'emptiness' in 1916, he obtained a central mass through the identification of an arbitrary constant of integration with a central mass. What was empty at the start suddenly become

populated with a constant mass. It was proffered that it was due to the asymptotic space dependence where gravitational forces come out of the woodwork and form the bridge between general relativity and Newtonian gravitation. Yet, there is nothing in the metric that would distinguish between the weak-field limit and the full gravitational equations. The Newtonian potential is always present, and so, too, its derivative the gravitational force.

This leads to the bigger problem of where gravity really resides in the Einstein equations. It is common knowledge that Einstein replaced physical forces with non-Euclidean geometry of one form or another. The traditional example of a massive object making an indentation into a trampoline is supposed to give the connotation that mass (and energy) cause the fabric of spacetime to warp. Yet, it avoids the obvious question of what is pulling the massive body down, if not for the physical action of gravity.

Thus, the geometry would be the consequence of the action of gravity not its cause. And since the other side of the equation contains an energy-mass tensor that does not contain explicitly the gravitational stress, it leaves open the annoying question of where is gravity in the Einstein field equations. Schwarzschild show that the solution to the vacuum field equations can contain a central mass, and almost four decades later, it was identified as a black hole! How mass did grow in that time! These 'pioneers' into the realm of black holes failed to realize the obvious: the Schwarzschild radius, representing the event horizon, constitutes a boundary which obviously can not be exceeded. These brave pioneers, switched the roles of time and space inside the event horizon, removed the singularity of the boundary, and attributed god knows what to an innocuous central mass which was only an integration constant! And in the process, the inner Schwarzschild solution threw the baby out with the bathwater.

The ensuing development of black hole thermodynamics confuses entropy with a convex function of the energy resulting in negative heat capacities and the impossibility of ever reaching a state of thermal equilibrium. The area theorem contracts the second law insofar as when two bodies, each at the same temperature, are brought into thermal contact there should be no increase in the entropy, contrary to the area theorem.

Gravitational waves are detected from using the linearized Ricci tensor without a

source. It is claimed that the waves are the result of cataclysmic collisions of massive black holes. But what about the putative gravitational waves nearer the sources? Einstein's theory remains completely silent. For, in fact, the Einstein field equations can't even solve the Newtonian resolvable two-body problem, and do not possess periodic solutions in the full nonlinear regime. So, in essence, it is a linearization around a wrong state describing a completely flat metric.

So how is all this accomplished by projects like LIGO and VIRGO? By implementing the original field equations which claim that the only types of trajectories that it can describe are trajectories of constant speed, or geodesics, with computer simulations that hack up space time into 3+1 dimensions, and make all sorts of simplifying assumptions to describe the acceleration of masses that, it claims, are the true source of the waves. The transition of a theory that describes the motion of heavenly bodies as trajectories of constant speed to one of accelerative motion is truly an act of pulling the rabbit out of the hat.

It seems almost a physical impossibility—and probably it is—to wed a theory that depends on different observers stationed at various locations to make measurements on the *same* system as in relativity with quantum measurements which are plagued by the destruction of interferences that take place in the course of measurement. In other words, what is measuring is unavoidable inextricably entangled with the phenomenon that is being measured, or said slightly differently, the destruction of interference between the particle and apparatus trying to observe it is precisely what is needed to get a consistent picture of the particle-wave duality. The proof that interference is, in fact, destroyed stands in the defence of the quantum theory of measurement, as David Bohm so eloquently argued.

Of course, this destruction of interference has no effect on macroscopic measurements carried out by interferometers. But when such macroscopic apparatuses delve into the microscopic domain at such incredibly small distances—of the order of one-thousandth the diameter of a proton—things become dubious to say the least. On this scale, the measuring device is destroying the interference it is trying to measure. There no panacea, like "quantum non-demolition" measurements, or "squeezing" techniques, because the greater precision that is achieved in one of the variables results in the greater uncertainty in its conjugate variable. The uncertainty principle is like a bursting damn: you plug up one hole and water comes gushing out of another.

As we will see, the Copilot uses hand-waiving arguments attempting to condone, if not justify such arguments, coming out with phases like 'writing it off as a nuance,"necessary simplifications,""given the complexity of," the "need for simplifying assumptions," "not in a way that we are commonly used to," to obviate the difficulties that our present understanding of cosmology presents. Ignorance, or the incapability of confronting the true nature of the physical problems, is no excuse of accepting nonsensical results and trying to justify them or at least make excuses for them. There is no rebuttal to the claim of chalking it up to new advance and technologies when there is theoretical confusion of what constitutes low and high energy limits, e.g., the linearized Einstein equations cannot be used right up to the inspiralling of two massive black holes.

Since it is a conversation, and we don't know where it will lead, there is often repetition, and the presentation of the same ideas in different contexts. I trust this will not detract from the grasping of the ideas which are presented.

Bernard Lavenda



1 What is Gravity?

... the eternal question

Sent by you:

The idea that gravity isn't a force, it's the curvature of space-time caused by the presence of mass-energy. removes the beast and replaces him with his footprints.

Sent by Copilot:

You're absolutely right! According to Einstein's theory of general relativity, gravity isn't a force in the traditional sense. Instead, it's the result of the curvature of space-time caused by the presence of mass and energy. This idea revolutionized our understanding of gravity, moving away from Newton's concept of it as a force.

The phrase "removes the beast and replaces him with his footprints" is a poetic way to describe how Einstein's theory replaced the idea of a gravitational force (the "beast") with the geometric curvature of space-time (the "footprints").

Sent by you:

I'd rather deal with the beast himself rather than his foot prints because the latter can lead to speculation and misconceptions of what the beast really is.

Sent by Copilot:

I see what you mean. Dealing directly with the "beast" (the actual force or phenomenon) can indeed provide a clearer and more tangible understanding, whereas interpreting "footprints" (indirect evidence or effects) can sometimes lead to misinterpretations or incomplete pictures. In the context of gravity, while Einstein's theory offers a more accurate model, it can be abstract and complex. Newton's concept of gravity as a force is more intuitive and easier to grasp, even if it's not as precise.

It's a bit like preferring a straightforward explanation over a more nuanced but complicated one. Do you find that this applies to other areas of science or life for you as well?

Sent by you:

But Einstein's theory obviate the real problem of determining the nature of the force we call gravity.

Sent by Copilot:

That's an interesting perspective. Einstein's theory indeed shifts the focus from understanding gravity as a force to understanding it as a geometric property of space-time. This shift can feel like it sidesteps the question of what gravity "really is" in a more intuitive sense.

While general relativity provides a highly accurate description of gravitational phenomena, it doesn't necessarily explain the underlying nature of gravity in a way that feels as direct as Newton's laws. This is one reason why physicists continue to explore theories that might unify general relativity with quantum mechanics, such as string theory or loop quantum gravity.

These efforts aim to provide a deeper understanding of gravity that reconciles its behavior on both cosmic and quantum scales.

Sent by you:

All the "results" of general relativity can be obtained by other means which removes the uniqueness of the theory. This I have discussed in my books, *A New Perspective*

on Relativity, Seeing Gravity, and The Physics of Gravitation. Although Seeing Gravity made it number 3 in BookAuthority's list of the 100 best general relativity books of all time, and number 2 of 34 the best Black Holes Books of all Time. Someone then read the book and found that it was neither in favor of general relativity nor the theory of black holes. Hence, it was subsequently removed because it explained what the theories aren't rather than what they seeming profess.

And even more important is the baggage that was dumped on the theory to fill it with things that it was never intended for, nor even dreamed of. But even trying to accommodate singularities and the like, you can never marry a continuous field theory with a discrete theory like quantum theory. And here is the rub: the tendency today to use the very big to measure the very small, completely ignoring, or using hand waiving arguments of why they can beat Heisenberg's principle, when, in fact, you can't.

It's not easy to confute detailed numerical calculations done on supercomputers, or validating a theory by matching one spectrum out of an infinitely number of other spectra that were computer generated.

It is a waste of time and money to squeeze out of theory what it was never meant to be. There are no periodic solutions to the Einstein field equations so why look for them? The same equations are incapable of solving the two-body problem so why use it to explain binary black holes and their coalesce? What justifies the use of the energystress tensor of a perfect fluid to describe even what distantly resembles the collision of black holes? The excuses of simplicity and being tractable do not suffice. You've simply got the wrong model and the wrong theory to apply it to.

2 Is Schwarzschild's exterior solution a vacuum solution?

... when a nobody became a some body.

Sent by you:

How can an arbitrary constant of integration determine a solution to the Schwarzschild metric? There can be no matching with the weak field limit, since general relativity detest the use of gravitation force in any context whatsoever.

Sent by Copilot:

The Schwarzschild metric is a solution to Einstein's field equations in general relativity that describes the gravitational field outside a spherical, non-rotating mass. The solution is characterized by a single parameter, the mass, M, of the object, and is given by:

$$ds^{2} = -(1 - 2GM/c^{2}r)c^{2}dt^{2} + \frac{dr^{2}}{1 - 2GM/c^{2}r} + r^{2}(d\theta^{2} + \sin^{2}\theta d\varphi^{2})$$

In this context, the arbitrary constant of integration can be interpreted as the mass M of the central object. This constant is determined by matching the solution to the weak-field limit, where the Schwarzschild metric should reduce to the Newtonian gravitational potential for large distances from the mass.

In the weak-field limit, the Schwarzschild metric approximates to:

$$g_{00} \approx -\left(1 - \frac{2GM}{c^2 r}\right) \approx -\left(1 - \frac{2\Phi}{c^2}\right),$$

 $\Phi = -\frac{GM}{m},$

where

is the Newtonian gravitational potential. This matching ensures that the Schwarzschild solution is consistent with the known behavior of gravity in the weak-field limit, where general relativity should agree with Newtonian gravity.

While general relativity does not use the concept of gravitational force in the same way as Newtonian mechanics, it does describe how mass and energy curve spacetime, which in turn affects the motion of objects. The Schwarzschild solution is a specific case of this, describing the spacetime geometry around a spherical mass.

Sent by you:

This is not the weak field limit and no approximations have been made on g_{00} Even notwithstanding your deceiving appearance that some approximation has been made, you would contend that in the non-weak gravitational limit, gravitational forces suddenly disappear?

Sent by Copilot:

In the context of general relativity, gravitational forces don't "disappear" in the nonweak gravitational limit; rather, the concept of gravitational force is replaced by the curvature of spacetime.

In strong gravitational fields, such as those near a black hole, the effects of spacetime curvature become very pronounced. Objects follow paths called geodesics, which are the natural paths in curved spacetime. These paths are influenced by the mass and energy present, but we don't describe this influence as a "force" in the traditional Newtonian sense.

Instead, we talk about how spacetime is curved by mass and energy, and how objects move within this curved spacetime. For example, near a black hole, the curvature is so extreme that it creates phenomena like event horizons and gravitational time dilation.

So, while the concept of gravitational force as used in Newtonian mechanics isn't applicable in general relativity, the effects of gravity are still very much present and are described by the geometry of spacetime.

Sent by you:

The Kruskal coordinates violate the principle of general covariance. While the original Schwarzschild solution breaks down at the event horizon, any coordinates transformation that allows one to prolong the solution is not equivalent to the original problem.

Sent by Copilot:

You raise an interesting point about Kruskal coordinates and the principle of general covariance. The Schwarzschild solution indeed has a coordinate singularity at the event horizon, which makes it appear as though the solution breaks down there. Kruskal-Szekeres coordinates were introduced to address this issue by providing a coordinate system that extends smoothly across the event horizon.

The principle of general covariance states that the laws of physics should take the same form in all coordinate systems. Kruskal coordinates are designed to respect this principle by removing the coordinate singularity at the event horizon, thus allowing the Schwarzschild solution to be extended in a way that is consistent with general relativity.

However, it's true that this transformation changes the way we interpret the spacetime geometry. While the Schwarzschild coordinates break down at the event horizon, Kruskal coordinates provide a more complete picture of the black hole's spacetime, showing that the event horizon is not a true physical singularity but rather a coordinate artifact.

This does not mean that Kruskal coordinates violate general covariance; rather, they provide a different perspective that is still consistent with the underlying principles of general relativity. The use of different coordinate systems to describe the same physical situation is a common practice in general relativity, and it helps to reveal different aspects of the spacetime geometry.

Sent by you:

In one coordinate system I have a singularity, and in another coordinate system that singularity miraculously disappears. And you're telling me that both describe the same

physics?!

Sent by Copilot:

I understand your skepticism. It does seem counterintuitive that a singularity can appear in one coordinate system and not in another. However, this is a feature of how general relativity handles different coordinate systems.

In the Schwarzschild coordinates, the event horizon appears as a singularity because the coordinates break down there. This is known as a coordinate singularity, not a physical one. When we switch to Kruskal-Szekeres coordinates, this coordinate singularity is removed, revealing that the event horizon is actually a smooth, continuous part of spacetime.

Both coordinate systems describe the same underlying physics, but they do so in different ways. The Schwarzschild coordinates are useful for understanding the spacetime outside the event horizon, while Kruskal-Szekeres coordinates provide a more complete picture that includes the region inside the event horizon.

This doesn't mean that the physical reality changes; rather, our mathematical description of it becomes more accurate. The true physical singularity, where densities become infinite, still exists at the center of the black hole (the so-called singularity), and this is present in both coordinate systems.

It's a bit like looking at a map: different projections can show different aspects of the same geography. Some projections might distort certain features, but the underlying geography remains the same.

Sent by you:

But different projections do not switch space and time coordinates!

Sent by Copilot:

You're right, different map projections don't switch space and time coordinates. The analogy was meant to illustrate how different coordinate systems can provide different perspectives on the same underlying reality.

In general relativity, the switching of space and time coordinates near the event horizon is indeed a unique and counterintuitive feature. This happens because the nature of spacetime itself changes in the extreme gravitational field of a black hole. In Schwarzschild coordinates, time and radial distance behave differently inside the event horizon compared to outside it.

Kruskal-Szekeres coordinates help us understand this by providing a coordinate system where the event horizon is not a singularity, allowing us to see that the event horizon is a smooth part of spacetime. This doesn't change the physical reality but rather gives us a clearer mathematical description of it.

The switching of space and time coordinates is a reflection of the extreme warping of spacetime predicted by general relativity.

3 Gravitational Force or Spacetime Curvature?

what came first the chicken or the egg?

Sent by you:

So what makes gravitational force appear in the weak-gravitational limit? And how do we know that when the gravitational forces are strong we should throw them out in favor of intentions in space time. And what causes these indentations if not the gravitational force itself?

Sent by Copilot:

Great questions! Let's break this down:

Gravitational Force in the Weak-Field Limit: In the weak-field limit, where gravitational fields are not very strong, the effects of spacetime curvature are small. In this regime, general relativity approximates to Newtonian gravity. This is because, at large distances from a massive object, the curvature of spacetime is gentle enough that the concept of a gravitational force, as described by Newton's law of gravitation, becomes a good approximation.

■ Transition to Strong Gravitational Fields: As we move into regions with stronger gravitational fields, the curvature of spacetime becomes more pronounced. In these regions, the simple concept of a gravitational force is no longer sufficient to describe the motion of objects. Instead, we must use the full machinery of general relativity, which describes gravity not as a force but as the curvature of spacetime caused by mass and energy.

■ Why Use Spacetime Curvature? The reason we switch to describing gravity in terms of spacetime curvature in strong fields is that general relativity provides a more accurate and complete description of gravitational phenomena. For example, it can explain the precession of Mercury's orbit, gravitational time dilation, and the bending of light around massive objects, which Newtonian gravity cannot.

■ What Causes Spacetime Curvature? The curvature of spacetime is caused by the presence of mass and energy, as described by Einstein's field equations:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Here, $G_{\nu\mu}$ represents the curvature of spacetime, Λ is the cosmological constant, $g_{\nu\mu}$ is the metric tensor, and $T_{\mu\nu}$ is the stress-energy tensor, which describes the distribution of mass and energy. The presence of mass and energy tells spacetime how to curve, and this curvature tells objects how to move.

In summary, in weak gravitational fields, the effects of spacetime curvature are small enough that we can approximate gravity as a force. In strong gravitational fields, the curvature of spacetime becomes significant, and we must use the full framework of general relativity to describe gravitational phenomena accurately.

Sent by you:

You say that only in the sixties was it possible to isolate the black hole at the center of the Schwarzschild metric mainly due to the work of Wheeler and Penrose on his singularity theorems. If the Schwarzschild radius represents the event horizon, what did people think was beyond it before these two gentlemen came on the stage?

Sent by Copilot:

Before the work of John Wheeler and Roger Penrose in the 1960s, the concept of what lay beyond the Schwarzschild radius (event horizon) was not well understood. The Schwarzschild solution, discovered by Karl Schwarzschild in 1916, described the spacetime geometry around a spherical, non-rotating mass, but the implications of the event horizon were not fully grasped.

■ Early Interpretations: Initially, the Schwarzschild radius was seen as a mathematical curiosity rather than a physical boundary. Many physicists thought that the singularity at the Schwarzschild radius was a sign that the solution broke down and that general relativity was incomplete in these extreme conditions. There was no consensus on what actually happened beyond this radius.

20 Juxtaposing Macroscopic & Microscopic Systems

... the Devil Lies in the details

Sent by you:

Black hole entropy is not entropy at all, and Hawking radiation is an error made by Hawking of using quantum field theory for the study of black holes. This confusion happens to be the norm rather than the exception. Very big macroscopic systems and very small microscopic system have been juxtaposed. The latter is limited by Heisenberg's uncertainty principle while the former is imperious to it. LIGO, the demonstration of the relation to the change in frequency to a difference in gravitational potential by the University of Colorado Boulder group are two examples where Heisenberg's uncertainty principle prevents them from doing so.

Sent by Copilot:

You've raised some thought-provoking points about the application of quantum field theory to black holes and the juxtaposition of macroscopic and microscopic systems. Let's break down some of these ideas:

■ Black Hole Entropy: The concept of black hole entropy, introduced by Bekenstein and Hawking, equates the surface area of a black hole's event horizon with entropy. This analogy has been influential but remains controversial. Critics argue that this entropy does not align with the traditional thermodynamic definition, which is a measure of disorder or the number of microstates.

■ **Hawking Radiation**: Hawking's prediction of black hole radiation arises from applying quantum field theory in curved spacetime. While this has led to significant theoretical insights, such as the potential for black holes to evaporate over time, it's true that some physicists question the validity of applying quantum field theory to such extreme conditions.

Heisenberg's Uncertainty Principle: This principle imposes fundamental limits

on the precision with which certain pairs of physical properties, like position and momentum, can be known. While it is crucial in quantum mechanics, its application to macroscopic systems like black holes is less straightforward. The principle is more relevant to microscopic systems, and its implications for macroscopic phenomena like gravitational waves detected by LIGO are still a subject of ongoing research.

■ LIGO and Gravitational Waves: The detection of gravitational waves by LIGO has opened new avenues for understanding the universe. However, the interplay between quantum mechanics and general relativity in these contexts is complex and not fully understood. The Heisenberg uncertainty principle does pose challenges, but it doesn't entirely preclude the study of such phenomena.

Your skepticism highlights the ongoing debates and challenges in theoretical physics. The intersection of quantum mechanics and general relativity remains one of the most profound and unresolved areas in modern science.

Sent by you:

Don't your statements :

- 1. the two atomic clock readings were taken from the same cloud of atoms, in a highly controlled energy state. In fact, the atoms ticked between two energy levels in perfect synchronization for 37 seconds, a record in terms of quantum coherence (that is, keeping quantum states stable) and that stability is essential for these measurements.
- 2. enabled the scientists to take their readings at two separate points, measuring the redshift across the cloud of about 100,000 ultra-cold strontium atoms. The redshift shows the change in the frequency of the atoms' radiation along the electromagnetic spectrum or, in other words, how quickly the atomic clock is ticking.

contradict Heisenberg's uncertainty period,

 $\Delta t \Delta \nu > 1,$

because the more precise the time interval the less precise is the frequency interval.

Sent by Copilot:

The statement you provided does not violate Heisenberg's Uncertainty Principle. Heisenberg's principle states that there is a fundamental limit to the precision with which certain pairs of physical properties, such as position and momentum, can be simultaneously known. Specifically, the more precisely one property is measured, the less precisely the other can be known.

In the context of atomic clocks and quantum coherence, the focus is on maintaining the stability of quantum states over time, which is crucial for precise timekeeping. The synchronization of atoms between two energy levels for 37 seconds demonstrates a high degree of quantum coherence, but it does not imply that both position and momentum (or other conjugate variables) are being measured with perfect precision simultaneously.

The measurements of redshift and frequency changes in the atomic clock are related to the energy levels and time, not directly to position and momentum. Therefore, the described experiment aligns with the principles of quantum mechanics and does not contradict Heisenberg's Uncertainty Principle.

Sent by you:

The uncertainty is between the time interval and the frequency shift!

Sent by Copilot:

You're right! In the context of atomic clocks, the uncertainty principle can indeed apply to the time interval and the frequency shift. The more precisely you measure the frequency shift, the less precisely you can measure the time interval, and vice versa.

However, the experiment described focuses on maintaining quantum coherence and measuring the redshift across a cloud of ultracold strontium atoms. This involves keeping the atoms in a stable energy state and measuring the frequency of their radiation over time. While there is an inherent uncertainty between time and frequency, the experiment's design aims to minimize this uncertainty to achieve highly precise measurements.

So, while Heisenberg's Uncertainty Principle is always at play, the experiment's success in maintaining quantum coherence for 37 seconds demonstrates that the scientists were able to control and minimize the uncertainties to a remarkable degree.

Sent by you:

The change in frequency of the atomic clocks is related to the uncertainty in the time measurements. So if perfect synchronization was obtained for 37 seconds nothing could be known about the frequency shift at two separate points in the cloud.

Sent by Copilot:

You bring up an interesting point about the relationship between time and frequency measurements. Heisenberg's Uncertainty Principle indeed implies that there is a tradeoff between the precision of time and frequency measurements.

However, in the context of the experiment you mentioned, the goal was to maintain quantum coherence and measure the redshift across the cloud of ultracold strontium atoms. The "perfect synchronization" for 37 seconds refers to the stability of the quantum states, which allows for precise measurements of the frequency shift over that period.

While it's true that perfect synchronization would imply a high degree of certainty in the time measurement, *the experiment's design likely involves sophisticated techniques to balance and minimize the uncertainties in both time and frequency measurements.* This balance allows scientists to extract meaningful data about the frequency shift even within the constraints of the uncertainty principle.

In essence, the experiment demonstrates a remarkable level of control over quantum states, enabling precise measurements that push the boundaries of our current understanding and capabilities.

Index

3+1 decomposition, 31, 32

aberration, 86 aberration, gravitational, 86 acceleration, centrifugal, 55, 56 acceleration, Coriolis, 56 acceleration, fictitious, 55 acceleration, gravitational, 56 acceleration, uniform, 62 accretion disc, 49, 209, 210, 216, 226 accretion disc, how it forms in a black hole, 220 adiabatic Universe, departure from, 282 AGN, 209, 210, 216, 224-226 AGN, bar, 214 AGN, power source of, 212 area theorem, 36, 38 Beltrami metric, 17, 54, 55, 61 black hole, at center of AGN, 216 black hole, binary, 128 black hole, conservation of energy, 229 black hole, information paradox, 39 black hole, supermassive, 215 black hole, thermodynamically unstable, 35 black hole, thermodynamics of, 34, 36, 294 blackbody, 35 Boltzmann principle, 40, 43, 44 boson, spin-2, see graviton, 306 Chandrasekhar limit, 232 chirp signal, 78, 89, 90, 139, 146, 150 closed system, 235 conservation, relativistic, 159 covariance, principle of, 14, 31, 32

curvature, sectional, 69, 70 Damour, Thibault, 317 dilation, time, 191 disc, uniformly rotating, 54 Doppler effect, 191, 192, 207 Doppler effect, for gravitational waves, 78 dumbbell, rotating, 97 Eddington limit, derivation of, 221 Eddington, Arthur, 84, 87, 156, 157, 205 effective one-body model, 317, 323, 329 Einstein condition of emptiness, 169 Einstein equations, adabaticity of, 51 Einstein equations, as equations of state, 51 Einstein equations, figuratively, 25 Einstein equations, quantization of, 51 Einstein equations, time reversible, 33 energy, non-localizability of, 27 entropy, as a measure of information, 37 entropy, Bekenstein-Hawking, 35, 36, 39, 41, 43, 46 entropy, black hole, 42 entropy, concavity of, 41 entropy, condition to increase, 33 equivalence principle, 35, 67, 68 equivalence principle, inapplicability of, 68 ergosphere, 228, 232, 234, 239 Essen, Louis, 182 event horizon, 39, 43, 49, 232 event horizon, adiabatic, 224 event horizon, filtering properties of, 225

Feynman, Richard, 93 foliation, 31, 32 forces, fictitious, 57, 68 forces, tidal, 68-70, 72 gauge, transverse-traceless, 134 general relativity, limitations of, 140 geodesic deviations, 71, 72 geodesics, 55, 60, 63 geodesics, deviations from, 72 geodesics, filtering of, 67 geometry, hyperbolic, 62, 63, 192, 199 geometry, of constant curvature, 256 geometry, Riemann, 69, 256, 258 GPS, 181, 182 gravitationa redshift, 304 gravitational lensing, 51, 82, 226 gravitational radiation, 96, 98, 99, 144, 151, 325 gravitational radiation, thermodynamics of, 294 gravitational redshift, 196, 207 gravitational stresses, filtering of, 57 gravitational time dilation, 177, 178, 180, 185, 191, 204, 275 gravitational waves, 161, 306, 307 gravitational waves, nonlinear, 130 gravitational waves, polarization of, 156 graviton, 87, 88, 306, 307 gravitons, nonlinear effects, 308 Guth, Alan, 51, 283 **GUTs**, 283 Hafele-Keating experiment, 181, 182, 204Hawking radiation, 35, 39, 228, 232, 241,

heat capacity, negative, 35, 38 Heisenberg uncertainty principle, 113, 333, 334 hohlraum, 103, 108 holographic principle, 40, 41 Hulse-Taylor binary, 94, 95 hyperfine transitions, 199 inflationary scenario, 53, 283 inflaton, 282, 284 inverse-square law, 122 Ives, Herbert, 292 Jacobson, Ted, 50 jets, relativistic, 209 Kruskal-Szekeres coordinates, 14, 19 Kundt, Wolfgang, 212 least action, principle of, 61, 63, 64 light, bending of, 87 Mössbauer effect, 194 measurement, quantum theory of, 112 momentum, angular, 65 Newton, second law, 61 Noether theorem, 66 numerical relativity, 31, 137, 166 Penrose process, 227, 232, 239 phase shifts, 119 phase space volume, 41 Planck length, 44 Planck oscillators, 35, 36 Poincaré disc model, 241 Poincaré, Henri, 74 polarization vector, 4D, 160

300

polarization, a spatial phenomenon, 156 polarization, LL, LT, TT, 158 post-Newtonian approximation, 166, 318 Pound-Rebka experiment, 181, 183, 193–195, 197 principle of covariance, 31 quadrupole formula, 99 quantum field theory, 35, 36, 241 quantum gravity, 54, 307 quantum non-demolition techniques,

112

radiation pressure, 88 radiation pressure, of a black hole, 222 radiation, blackbody, 245, 296, 307 radiation, quadrupole, 95, 298–300 radiation, thermal, 300 radiative efficiency, of a black hole, 222 refraction, index of, 65, 66, 178 relativistic jets, 211 Ricci tensor, 69, 70, 72 Ricci tensor, linearized, 100, 308 ringdown, 317, 321, 322, 324 Ritz, ballistic theory, 199 Robertson-Walker metric, 286 Romatschke, P, 196 rotating disc model, 54

scale factor, 255, 256 second law, 33, 46, 49, 232 second law, non applicability of, 50 Snell law, 192, 200, 206, 253 speed of light, as a unit of measurement, 197, 200, 248 spherical waves, exclusion of, 160 Stefan-Boltzmann law, 95, 295, 299 Stefan-Boltzmann law, for gravitational radiation, 298, 299

temperature, of a black hole, 36 thermal equilibrium, 37, 38, 109 time, proper, 64 triangulation, 187 trilateration, 201

van Flandern, Tom, 188 vector potential, 158

waveform templates, 315 white dwarfs, 181

Bernard Lavenda

Reframing Gravity and Relativity: A Critical Dialogue on Black Holes, Spacetime Curvature, and Quantum Theory

Almost four centuries have passed since Galileo's publication of Dialogo sopra i due massimi sistemi del mondo. In that time the Universe has expanded and, so too, our concepts of it. In Galileo's time it was the Ptolemyan versus Coperican theories that was at the center of discussion, while today it is the unharnessed extrapolation of General Relativity to include quantum theory, and theories it was never meant to incorporate. Instead of looking for new avenues to develop, the General Relativity has been pushed well beyond its limits of validity.



