Quantum Gravity: Have We Been Asking The Right Question?

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Abstract

To get the correct answer one must ask the correct question. In the field of Quantum Gravity the question has been how do we quantize General Relativity or derive a quantum theory which becomes General Relativity at low energies. Observing that Quantum Field Theory was the result of making Quantum Mechanics into a relativistic theory, I asked myself why not make QFT obey the principles of GR? I answered this question with a model I call Relativization. In a series of three papers I presented an answer to this alternative question which gives finite results for everything from black holes to particle physics [Farmer(2014a), Farmer(2014b), Farmer(2015)]. However, others may answer this question more elegantly than I have. Have we by studying Quantum Gravity for 50 + years been asking the wrong question, and thus experiencing difficulty, all this time?

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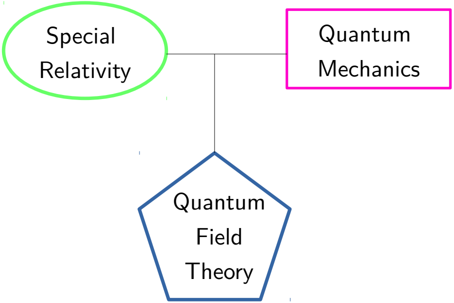
- There have been many attempts to do this such as String/M-Theory, Loop Quantum Gravity, and others. All of which met with some success. Each has hit various roadblocks.
- So I decided to look at this as if I was a Martian, almost as if I had never heard of Quantum Gravity.

Another Point of View

- One way physical theories develop is by the recognition that one model is somehow more fundamental than the other.
- One can look at this as a sort of theoretical family tree.

Another Point of View



Special Relativity

Quantum Mechanics

Quantum Field Theory

Figure: A theoretical family tree. The theory on the left is taken as more fundamental than the theory on the right. The one on the left is sort of the father theory and the one on the right is the mother theory. The "family" the theory belongs to being determined by the father theory.

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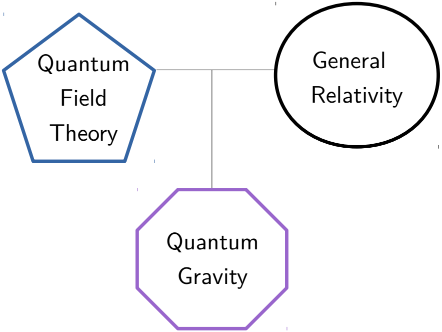
Quantum Field Theory

General Relativity

Quantum Gravity

Figure: A theoretical family tree where big daddy QFT sort of "gives his name" to the child theory Quantum Gravity. Put this way we have been trying to create a certain kind of child theory.

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- The underlying assumption of all theories of Quantum Gravity has been that quantum is somehow more fundamental than relativity. That General Relativity needs to be quantized in some way.
- This is due to the wild success of Quantum Field Theory which is the result of making Quantum theory obey Special Relativity.
- Maybe that assumption is what is holding us back? Maybe we have been trying to force nature in a direction it cannot go on this case.

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A Definition

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Relativization the act or result of making relative or regarding as relative rather than absolute [Websters(2015)].
In the context of physical theories Relativization means the act or result of making a theory obey the principles of Special or General Relativity.

The Question

- Given the difficulty of traditional quantization why not try asking a different question towards the same ends?
- An alternative question would be “How can we make QFT comply with the principles of General Relativity?”
- Put another way, “How can we relativize QFT?”

GR + QFT from Another Point of View.

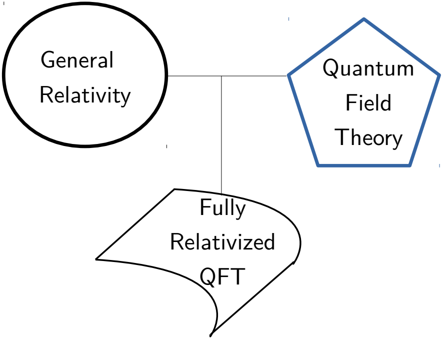

Figure: Instead of a quantization of General Relativity I propose *relativization* [Websters(2015)] of Quantum Field Theory. Instead big black hole filled General Relativity is the father and little dainty QFT is the mother. The resulting child theory is then more fundamentally a relativistic theory, not a quantum theory.

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- The question was stated in terms of the relationships between Hilbert spaces and Riemannian manifolds.
- The basic axioms and principles that would describe a relativized QFT were set down.
- Numerical calculations which show that the resulting simplest relativized standard model can reproduce Hawking radiation in a way which agrees with observations so far were done. (i.e. The black holes can form nicely and don't blow themselves apart. Although there are some small differences or corrections from my model.)

Quantum Gravity by relativization of Quantum Field Theory

- In “Quantum Gravity by relativization of Quantum Field Theory.” [Farmer(2014a)] I first posed the question and addressed the fundamental mathematical structure of relativized quantum field theory. The paper drew on approaches such as geometric algebra and QFT in curved space time.
- A closer look at what it means to have Hilbert space in the same model as one with a curved Riemannian background and established a formalism for discussing Hilbert spaces “on top of” locally flat space-time “on top of” globally curved space time.

Fundamentals of Relativization

In "Fundamentals of Relativization"[Farmer(2014b)] I proposed the following collection of principles as axioms.

RELATIVIZATION PRINCIPLE: *All physical theories must obey the Einstein Equivalence Principle*. "That for an infinitely small four-dimensional region, the relativity theory is valid in the special sense when the axes are suitably chosen." [Einstein(1916)] In other words physical theories must be formulated in a way that is locally Lorentz covariant and globally diffeomorphism covariant. Stated with equations.

$$x^\mu = e^\mu_a x^a$$

x^a is a vector in the locally flat space near a point.
e^μ_a is a vielbien connecting local flat space to the globally curved manifold.
x^μ is a vector in the curved space time manifold.

Fundamentals of Relativization

- **SPECTRUM CONDITION:** All possible states of a QFT will be in the Fock-Hilbert space $\mathcal{H}$. An operator on $\mathcal{H}$ must map states to other states in $\mathcal{H}$.
- **NORMALIZATION CONDITION:** The inner product on $\mathcal{H}$ must be in a set isomorphic to the division algebras $\mathbb{R}$,$\mathbb{C}$,$\mathbb{H}$, $\mathbb{O}$. [Baez(2012)] For example an inner product on $\mathcal{H}$ of the form $\langle\psi|\,\psi\rangle = j^a$ with $j^a \in \mathcal{M}$ and $\forall\ |\psi\rangle \in \mathcal{H}$.
- **LOCALITY PRINCIPLE OF QFT :** QFT interactions occur in the locally flat space at the point of interaction. The propagation of particles between interactions is governed by Relativity.
- **SPECIFICATION CONDITION:** Relativized QFT's are defined by the above and the tensor product of their state space with Minkowski space. For a theory T, $T = \{\mathcal{H}, \mathcal{H}\otimes\mathcal{M}, A(\mathcal{H}\otimes\mathcal{M})\}$ (Inspired by a similar statement in [Hollands and Wald(2014)].)

Fundamentals of Relativization

- Following those axioms I was able to work through numerous mathematical steps detailed in [Farmer(2014b)] to a modification of the standard model to include a relativized gravity in which local QFT interactions influence the curvature of space time and vice versa.
-

$$\begin{aligned} L = \sqrt{-g}\Big(-\frac{1}{4}F^{ab}F_{ab} + i\bar{\psi}\gamma^a D_a\psi + \psi_i g_{ij}\psi_i\phi + h.c. \\ + |D_a\phi|^2 - V(\phi) + R - \bar{\phi}\gamma^a R_{ab}\phi\gamma^b\Big) \end{aligned}$$

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- R_{ab} is an operator which tells how QFT interactions effect the curvature of space time.
- $\widehat{R_{ab}} = \left(d\langle\phi|\phi\rangle(\gamma^{0})^{2}\wedge\gamma_{b} + \langle\phi|\phi\rangle(\gamma^{0})^{2}\wedge\gamma_{c}\wedge\langle\phi|\phi\rangle(\gamma^{0})^{2}\wedge\gamma_{b}\right)\langle\phi|.$

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- Then derived the locally correct gravitational modification to a QFT interaction $R_0 \propto \Lambda$.
- $$\overline{|M_{GG}|} = \frac{1}{2}\left(\bar{\phi}\gamma^{a}R_{ab}\phi + \bar{\phi}\gamma^{a}R_{ab}\phi\right)\gamma_{a}\gamma^{b} \approx R_0 \ Cosh(\hbar p)$$

Fundamentals of Relativization II with Computational Analyses

- In “Fundamentals of Relativization II with Computational Analyses” [Farmer(2015)], using Mathematica I modeled black holes with the following equation in which $x = \gamma^a x_a$. (L here designates am arbitrary length scale.)
- $$-\frac{L}{hc}\frac{\hbar^2\psi''(x)}{2M} + \frac{\hbar^2 R_0}{2M}\frac{L}{hc} Cosh(x)\psi(x) - \mathrm{En}\frac{L}{hc}\psi(x) = 0$$

Fundamentals of Relativization II with Computational Analyses

- Which with the proper boundary conditions even and odd energy eigenstates and eigenvalues were found in terms of Mathieu functions.
- $$\psi_a(x) = \frac{e^{i\left(n+\frac{1}{2}\right)}\text{MathieuC}\left[a_{n+\frac{1}{2}}\left(-2L^2R_0\right), -2L^2R_0, \frac{ix}{2L}\right]}{\text{MathieuC}\left[a_{n+\frac{1}{2}}(-2L^2R_0), -2L^2R_0, \frac{i}{2}\right]} \;;$$

  $$\text{En} = -\frac{\hbar^2 a_{n+\frac{1}{2}}\left(-2L^2R_0\right)}{8L^2M}$$
- $$\psi_b(x) = \frac{e^{i\left(n+\frac{1}{2}\right)}\text{MathieuS}\left[b_{n+\frac{1}{2}}\left(-2L^2R_0\right), -2L^2R_0, \frac{ix}{2L}\right]}{\text{MathieuS}\left[b_{n+\frac{1}{2}}(-2L^2R_0), -2L^2R_0, \frac{i}{2}\right]} \;;$$

  $$\text{En} = -\frac{\hbar^2 b_{n+\frac{1}{2}}\left(-2L^2R_0\right)}{8L^2M}$$

Fundamentals of Relativization II with Computational Analyses

- In the latest paper[Farmer(2015)], an expression for a black hole's luminosity was derived. (The "E" in the denominator stands for an elliptic integral.)

$$L_{\mathrm{BH}} = \frac{\left| \dfrac{\hbar^2 \left(a_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) + b_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) \right)}{L^4\,M\,t_p} \right|}{(64\,\pi)\exp\left(\dfrac{i\,L\,E\left(\frac{i}{2} \,\middle|\, -\dfrac{16\,L^2\,R_0}{-8\,R_0\,L^2 + a_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) + b_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right)} \right) \sqrt{\dfrac{\hbar^2 \left(4\left(1+e^2\right) L^2\,R_0 - e\left(a_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) + b_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) \right) \right)}{L^2\,M}}}{2\,\hbar \sqrt{\dfrac{e\left(a_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) + b_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) \right) - 4\left(1+e^2\right) L^2\,R_0}{a_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) + b_{n+\frac{1}{2}}\left(-2\,L^2\,R_0\right) - 8\,L^2\,R_0}}} \right)}$$

Fundamentals of Relativization II with Computational Analyses

Using the following approximation, and the effective black body temperature to luminosity relationship, I computed the temperature due to Hawking type radiation from a set of typical astronomical masses. Specifically a one kilogram black hole, an 8 $M_\odot$ black hole and Sagittarius A*.

$$L_{BH} \approx \frac{1}{16}\left|\frac{\hbar^2\left(a_{n+\frac{1}{2}}\left(-8G^2M^2R_0\right)+b_{n+\frac{1}{2}}\left(-8G^2M^2R_0\right)\right)}{G^4M^5t_p}\right|$$

The temperatures would be for the one kilogram, eight solar mass, and super massive Sagittarius A* black holes would be.

$$T_{\mathrm{BH}} = \frac{\sqrt[4]{L_{\mathrm{BH}}}}{2\sqrt[4]{\pi}\sqrt{G}\sqrt{M}\sqrt[4]{\sigma}}$$

$$\{5.5\times10^{10}, 1.4\times10^{-44}, 5.9\times10^{-54}\}K$$

Fundamentals of Relativization II with Computational Analyses

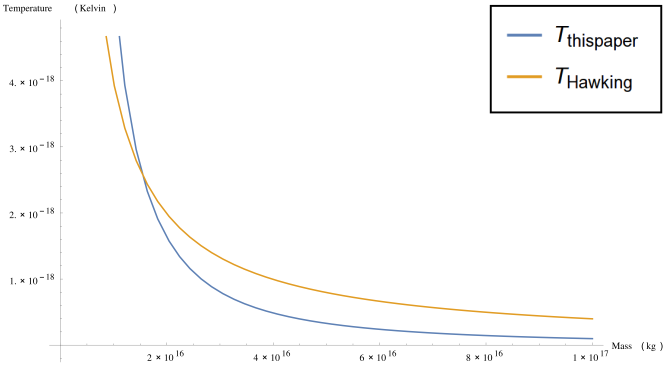

Figure: A plot of temperature vs mass comparing my model to the Beckenstein-Hawking model. The predictions of my model derived by very different means are very close to the accepted semiclassical model. [Farmer(2015)]

Fundamentals of Relativization II with Computational Analyses

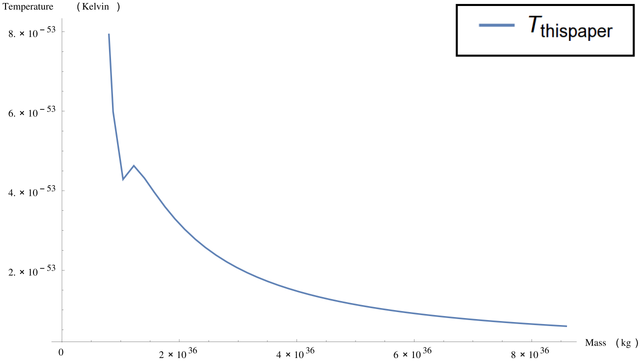

Figure: At larger mass scales my model predicts much colder black holes, and a possibly observable ripple in their temperature-mass relationship. [Farmer(2015)]

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- With few resources and little time I was able to come up with a reasonable model to answer this question.
- Imagine what might happen after 50 years of studying this approach with the proper support and a number of much more talented researchers.
- The right question should lead to an answer in a way which is simple or at least tractable. This question seems more tractable based on the fact I was able to start to answer it (and I'm not that smart).

Thank you for your time.

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