Notes on the unification of fundamental physical phenomena via geometric principles

December 23, 2013

The motivation of this program: Progress in fundamental physics has stalled at the point of the unification of gravitation with quantum mechanics (QM). Almost all the approaches to this problem have been various way to "quantize" gravity. All have failed. The most spectacular failure is string theory which hasn't generated any new physics despite decades of effort by the majority of the fundamental theorists in the world. A dramatically new approach is required. I am currently reading Lee Smolin's book on that episode called *The Trouble with Physics*.

In unifying gravity with quantum mechanics, the two obvious approach that should immediately occur is 1) apply the principles of QM to gravity or 2) apply the principles of general relativity (GR) to the quantum realm. Approach 1 has been exhausted. Approach 2 has hardly been tried at all. Even loop quantum gravity hinges on the basic principle of quantization applied to the geometry of space-time.

Hence one of the objectives of this program is to find geometric principles that underlie the principles of quantum mechanics.

The foundations of quantum mechanics remain murky while the foundations of GR are clean and intuitive. GR is a beautiful theory based on principles that make sense. The approach most likely to succeed in the unification program is to extend GR, not spread the quantum cancer.

When we think of existence—ontology—in a realist mindset we think of objects with extent and shape that move and change. Extent and shape are geometry by definition. Einstein (special relativity) showed us that movement and change was simply geometry in a unified spacetime. Einstein (GR) showed us that force—the gravitational force that is, the generator of movement, is also geometry, namely the curvature of spacetime. Hence:

> extent & shape = geometry
> movement & change = geometry
> force = geometry

Principles for Geometric Unification:

The fundamental principle: *All ontology is geometry.*

1. Spacetime, the foundational geometric object can be represented as a Riemannian manifold of 4 + *n* dimensions. The metric has a Minkowski signature, that is, there is one timelike dimension. The extra *n* dimensions are compactified so as not to be observable directly. Their existence is inferred by the existence of the electroweak and strong forces.

2. All physical laws are geometric identities of the manifold.
3. The only formal, exact symmetry is general covariance of the spacetime manifold. This follows from the logical principle of representational invariance, nature cares not about our representations.
4. All forces are connections of the space-time manifold. The gauge invariance of the electro-weak and strong forces is derived from the general covariance of the space-time manifold.
5. The relative strength of the forces is due to the relative scale of the dimensions of spacetime they represent. Gravity is weak because the scale of spacetime in the normal three dimensions is large. The other forces are strong because of the tiny dimensions of compactified dimensions that gives rise to them. *[How does this follow from the basic thesis?]*
6. Matter (particles) is made of irreducible topological objects like knots. Fermions are knots that cannot be superposed, they remain distinct. Bosons are more like windings in that they can add. Topological invariants of the knot give rise to quantized properties like charge.
7. Charge and mass are related to a basic curvature measure.

Some conceptual consequences:

1. Einstein's equation is explained since the micro-curvature of knots combines to produce the macro-curvature of four dimensional spacetime.
2. The uncertainty principle is explained by the non-local nature of particles (similar to the existence of an uncertainty relation for waves).
3. Bell's theorem is obviated by the non-local nature of matter and the non-local nature of the EPR measurement.

Other guiding principles:

1. Realism: There exists a reality apart from our human perception of it. Martin Gardner says it well:

   The hypothesis that there is an external world, not dependent on human minds, made of something, is so obviously useful and so strongly confirmed by experience down through the ages that we can say without exaggerating that it is better conformed that any other empirical hypothesis. So useful is the posit that it is impossible for anyone except a madman or professional metaphysician to comprehend a reason for doubting it.

2. The world is deterministic. This amounts to a belief that there are laws that govern the time evolution of the universe and that those laws are, in principle, exact. Given the assumptions above, this can be stated rigorously.
3. Locality is implied by the geometric principle outlined above.

4. Probability is a logical concept, having nothing to do with objective reality. The subjective or Bayesian interpretation of probability is the only coherent interpretation available. This principle eliminates much of the embarrassment in QM.

How to make progress with this program?

1. Does an uncertainty relation hold for all objects with spatial extent? How to prove?
2. How to obviate Bell's theorem. Does spatial extent do the trick? Look into what is required physically to produce entanglement. It is usually some kind of symmetry principle that produces correlations between the spatially separated entities. The objects had to have proximity in the past and be translated. The result of that translation involves geometric variable along the path. On the other hand, the measurement itself is non-local. Is that the simplest answer?
3. Is any interpretation of QM that interprets quantum probabilities in the Bayesian sense implicitly local as Fuchs claims?
4. Research Kaluza-Kline type theories. What dimension is required to get the gauge symmetries of the standard model?

<u>*December 27, 2013*</u>

I am assembling resources in the current approaches to fundamental physics. Question 3 will be asked in my next email to Fuchs.

<u>*December 30, 2013*</u>

Bell's and related theorems are the crux. Some basic questions:

1. How does a subjective view of probability affect the Bell results? if at all.
2. How is the preparation of an entangled state affect the result? There is some non-trivial physics involved here. Entangled states don't just magically appear, there must be some physical process to prepare them and some symmetry principle, like conservation of angular momentum to give substance to the entanglement. (same a number 2 above).
3. How would spatial extent of fundamental entities affect the Bell result?
4. What are the critical unspoken assumptions in the derivations?

<u>*December 31, 2013*</u>

What are the arguments against an objective indeterminism?

1. The argument that objective indeterminism violates special relativity by requiring a preferred notion of simultaneity.
2. The argument from the future. Looking back we will perceive a definite past that contains our current present. From that vantage point everything will appear determined.
3. The argument from the appearance of macroscopic determinism. How does micro-indeterminism create the appearance of macro determinism? How is amplification of micro-indeterminism avoided.

One way to explore this is to discover more about what Fuchs calls the pluriverse, a concept he borrowed from William James (A Pluralistic Universe). I've ordered the book from Amazon.

In the meantime, Fuchs slapped me for discussing Ontic interpretations of QM. I'll apologize so he keeps corresponding. Also in the meantime, I came across (in Fuchs yellow book) another article by Jaynes that directly addresses the Bell theorem. He points out one error in the derivation: that Bell confuses conditional probability as encoding a causal relationship, whereas in the Bayes interpretation it represents an inference.

January 1, 2014

The probabilities encoded in quantum states describe the uncertainty in the outcomes of our (the agent's) possible interactions with (measurements of) the quantum system.

January 7, 2014

Read a few papers by Antony Valentini, now at Clemson. He is the world's foremost advocate for the de Broglie-Bohm pilot wave theory. In one of them, he analyses a traditional QM measurement as expressed by an operator in a Hilbert space from the pilot wave perspective. The result is fascinating. The traditional measurement basically transforms the quantum system into the image of the measurement. The answer you get has much more to do with the question you ask than the system supposedly being interrogated.

Is this the effect that Fuchs sees from his neo-Copenhagen perspective as creating the result? I think so.

The pilot wave approach seems to be a source of some great fundamental insights. One key that relates to the geometric program is to understand the nature of the non-locality.

I plan to reach out to Valentini by email this weekend. Here's hoping that he is more like Fuchs than Smolin.

January 12, 2014

A spate of articles from 2013 declare that on the basis of no findings from the Large Hadron Collider at CERN, supersymmetry as a theory is all but dead. The most natural supersymmetric theories predict that the lightest mass superpartners would be in the range to be detected by the LHC. So far nothing. From the standpoint of geometric unification, this is not surprising. Fermions are topological entities while bosons are identified with connections. They are geometrically distinct with no natural symmetry relationship or pairing between them.

Back to the Jaynes article. It points out two problems. The first is the error in conflating conditional probability with causality. The second is a logical problem with all no-go theorems. They attempt to prove what cannot be done, which presupposes that one can anticipate all possible way it could be tried. They presume to be able to anticipate the creativity of future generations.

January 18, 2014

Question 1: has anyone addressed the logical issue Jaynes has raised with Bell result? I found one paper by Richard Gill (2008), not yet read. Are there others? More recent work by Colbeck & Renner (arXiv:1208.4123v2) make the same error that Bell did, conflating causality with inference. This is the view of objective probability and untenable.

Question 2: what is the significance of the new no-go theorems by Pusey et al (arXiv:1111.3328v3)? What Fuchs calls the ontological flesh feast.

Question 3: how to interpret the existence of the pilot wave theories. The perspective of standard measurement it provides is telling.

Question 4: the older ideas of Fuchs on how the apparent deterministic/classical world emerges from a quantum substratum. inherently it traces to the disturbance/information tradeoff.

Question 5: the significance of unitary evolution and reversibility. There is a strong connection to determinism.

I've now read Gill and he addresses the Jaynes concern in a very superficial way. The key issue is that Bell's application of the conditional probability rule contains an assumption that directly causes the deviation from QM. Gill constructs a classical situation where Bell's factorization is valid, but that does not prove that the assumption is valid for all locally realistic theories. Jaynes constructs a classical situation where such an assumption is clearly invalid. The issue comes down to entanglement. Jaynes example was balls drawn in order from the same urn. That sameness imposed a logical connection between the outcomes. The Gill example had a logical independence in the outcomes.

January 19, 2014

I've now thought more about this. I believe Gill is right and Jaynes is wrong.

January 25, 2014

The crux of the Bell issue is the dependence of the *outcome* at B on the measurement *setting* at A. How can such a dependence arise? One simple way is that in order to create an entangled pair of states, the subsystems must have been co-located some time in the past

January 26, 2014

Following up more on the issue of entanglement. Entanglement arises because of the imposition of some conservation law, typically the conservation of angular momentum. The system is created in a state of known total angular momentum. This global constraint then imposes constraints on the subsystems. In Bell-like situations, this constraint is used as a primary means to calculate the joint probabilities. My question is this: If we treat conservation of total angular momentum as prior information in the sense of Bayes, along with other symmetries of the problem, how far can we get in deriving the correct quantum correlations? Tried a bit. The challenge is in translating the constraint into something that affects the probabilities except in the case where $\theta = 0$ or π. Those points are easy. The other success was in getting the relation for P(AB) into a squared function of θ. But how to show the function is the sine? I know there is more info in the conservation constraint. How does it manifest itself for intermediate values of θ?

January 31, 2014

So can all entanglement be explained as knowledge about some global aspect of the system? This knowledge imposes constraints on what can be simultaneously said of the subsystems giving rise to correlations.

March 8, 2014

Just finished reading Davies' interview book *The Ghost in the Atom*. I found the interviewer's ideas far too prominent. But the interviews with Bell and Bohm were interesting. The Wheeler interview certainly shed some light into where Fuchs gets some of his ideas. The Bell comment of most interest:

You know, one way of understanding this business is to say that the world is super-deterministic. That not only is inanimate nature deterministic, but we, the experimenters *who imagine we can choose to do one experiment rather than another, are also determined. If so, the difficulty which this experimental result creates disappears.*

Q: Free will is an illusion — that gets us out of the crisis, does it?

That's correct. in the analysis it is assumed that free will is genuine, and as a result of that one finds that the intervention of the experimenter at one point has to have consequences at a remote point, in a way that influences restricted by the finite velocity of light would not permit. If the experimenter is not free to make this intervention, if that also is determined in advance, the difficulty disappears.

I wonder what he means by this? Clearly he seems to believe free will and determinism are incompatible. But which drives the result? If the experimenters are physical entities and governed by deterministic laws does that obviate Bell's theorem and restore the possibility of local realism? How does the derivation of his theorem depend on the free choice of the experimenter? I'll ask Fuchs

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Here are my comments and notes to follow up on Chris Fuchs yellow book (*Coming of Age with Quantum Information*).

pages 73-75. James quote on indeterminism. Stapp quote on determinism and free will. There is a disturbing conflation of QM and free will. Confusion ladled on top of confusion.

Page 146. Nice series of Jaynes quotes from three papers. **print and read the entire papers. (printed)

page 161-162. Musings on the difficulty in defining objective indeterminism. I definitely agree. Speculation that quantum indeterminism is closely related to entanglement.

Page 167. The psychological arrow of time. This is also a part of the puzzle. Is it significant?

Page 172-173. Complaints about hard core bayesians who seek hidden variable theories. Does a probability assignment imply improvement in knowledge is possible? Not necessarily. It depends.

*March 9, 2014*

Page 235. Good quote from Heisenberg: *What we learn about is not nature itself, but nature exposed to our methods of questioning*. This an important point to always keep in mind, for all scientific inquiry. The answers we get are often greatly shaped by the questions we ask. Hence it is critical that we question the questions. What if we ask different question? What if we look at things another way? In QM, it is related to the fragility of quantum system. The questions we ask directly change the state in such a way as we can't tease apart what is the result of our question and what was there before. What is subjective versus what is objective.

Page 241. Another Jaynes quote. This one from an article that had quite a bit on QM and some errors Jaynes perceived in the derivation of Bell's theorem. See notes from Jan 14.

Page 243. A good list of questions about the existing Hilbert Space formalism of QM. What compels this formalism?

Page 254. A reference to Bell that I had not seen before.

Page 258. Nice quote from Pauli on complementarity.

Pages 267-270. This is Fuchs' reply to the naive realism expressed by most Bayesians. His punch is the slogan that *maximal information is not complete information*. I really don't have a problem with this statement, but I don't see how this defeats the notion of realism.

Page 318. A passage about Liouville and classical mechanics. I ask the questions: Is conservation of information a consequence of determinism? If such a thing holds in QM, does this prove determinism? Indeterminism only enters QM through the process of measurement. Otherwise it is deterministic. **research the Liouville stuff.

Page 348. On the existence of an objective reality.

Page 403. Another Jaynes quote.

Page 438. Discussion about the principal principle of David Lewis. **research this. I did to a limited degree. David Lewis who died first stated the principal principle in the mid 1980's. It basically relates chance to probability. If you have definite knowledge of the chance of an event, your probability should equal the chance. Very straightforward. But apparently Lewis perceived some problems and modified it to the new principle in the mid 1990's. Here is another project: apply my modified decision that uses the floor, to the two envelope paradox.

Page 491. A good quote from Zelinger about indeterminism. And a good discussion on entanglement.

Based on all these notes, I have a lot of stuff to research. My to-read pile is enormous. I'll add indeterminism to the list. Is there a coherent description? I need a structured approach.

I want to bring an important question to the top of the queue. Is the uncertainty principle an indicator of the extended nature of fundamental entities? How does this work? Can one say that uncertainty principle iff extended? Or a weaker version extended implies uncertainty?

On the surface, it seems that some kind of uncertainty relationship must hold. If an entity is not localized any property of the entity must be found by integrating some quantity over the extent of the entity. In this case, the uncertainty in position is on the order of the spatial extent of the entity while the property obtained by integration is precise. That is one end of the spectrum. If one precisely specifies the position, the uncertainty of the property is maximized. You only have the single value at that precise point.

This is proved rigorously for waves in, for example, Elmore and Heald, *Physics of Waves*.

March 22, 2014

I have finished reading the Jaynes papers to include re-reading the quantum probability paper. several items of interest.

In one of the papers Jaynes muses over the importance of the de Broglie relations: E=hν and p=h/λ. These fundamental relations are the link between the particle and the wave descriptions of matter. In both cases they are related by Plank's constant. But in special relativity E and p are just different components of the four vector. First tack is to see how energy and momentum are carried by a classical wave packet, then try to find some analogy with Plank's constant.

In the quantum probability paper Jaynes makes a startling aside: *For example, 100 years ago it was a much discussed problem how material objects can move through the aether without resistence. Yet a different way of looking at it would have made the mystery disappear without any need to dispense with the aether. One can regard material objects, not as impediments to the "flow" of aether, but as parts of the aether ("knots" in its structure) which are propagating through it. On this way of looking at it, there is no mystery to be explained. As a student at Princeton many years ago, I was fascinated to learn from John Wheeler how much of physics can be regarded as really only geometry, in this way.*

I can't believe I didn't highlight that quote when I first read the paper. In the same paper we find this: *the probabilities we seek, which are to express the incompleteness of the information in a pure state in terms of a set of mutually exclusive possibilities (call it an "ensemble" if you like), cannot be the usual things called "probability" in the QM* *textbooks. The human information must be represented in a deeper "hypothesis space" which contains the phases as well as the amplitudes.*

This seems to be part of Fuch's QBism program.

June 3, 2015

I have some renewed interest in this triggered by reading *Quantum, Einstein, Bohr, and the Great Debate About the Nature of Reality* by Manjit Kumar.

1. Matter, consisting of space-time entities, have both distributed and discrete properties. Wave-particle duality is thus explained. A measurement process can perceive (or couple with) one aspect at a time. A particle-like measurement will tease out a topological property like charge or mass-energy. A wave-like measurement couples with the time-dependent, extended nature.
2. The EPR *measurement* of Bell's theorem is inherently non-local. It compares the direction at one location to the direction at another.

June 26, 2015

Following up a little to the June 3, 2015 entry. A particle-like result is demanded by a particle-like measurement. It requires the entirety of the topological entity, not pieces. Motion is governed by a wave equation. This brings in the time dimension. It is *how* entities are extended in time.

A few notable passages from the book related to this project:

Page 215. *Schrodinger believed that the square of the wave function of an electron was a measure of the smeared out density of electric charge at location x at time t.* This ties back to item 1. The charge of electron is a non-local property, a topological property. It cannot be perceived except in the whole. This is a clue to the Born probabilities. The question is where the uncertainty comes from and why can we describe it so well via probabilities.

Page 239. Bohr's interpretation of the uncertainty principle as a result of the wave-like nature of matter. I had not realized that Bohr had this insight. It is certainly not routinely taught, nor the fact that all waves exhibit an uncertainty relationship. This seems to be a strong anchor point for my project. It is also an error in my book to be corrected in the next edition.

Page 261. *In February 1927, as Bohr was edging toward complementarity, Einstein had given a lecture in Berlin on the nature of light. He argued that instead of either a quantum or a wave theory of light, what was needed was 'a synthesis of both conceptions.' It was a view he had first expressed twenty years earlier.* The program described here provides such a synthesis.

Fascinating book. Bohr and his followers believed they had decisively won the debate, but they never addressed Einstein's concerns and the interpretation they left behind has damaged students for 80 years. It spawned crazy ideas like the many worlds and others. Only now are some starting to get out of the shadow. Bell's theorem is now the great impediment. I see cracks in that facade as well. That might be the best first step in untying the Gordian knot.

Two avenues to pursue:

1. Keep working the angle from the January 26, 2014 entry.
2. Construct a non-local set of hidden variables that produces the quantum result. What is the nature of such a set? What characteristics does the quantum result impose on the non-local hidden variables? Can the non-local hidden variables be expressed as a field?