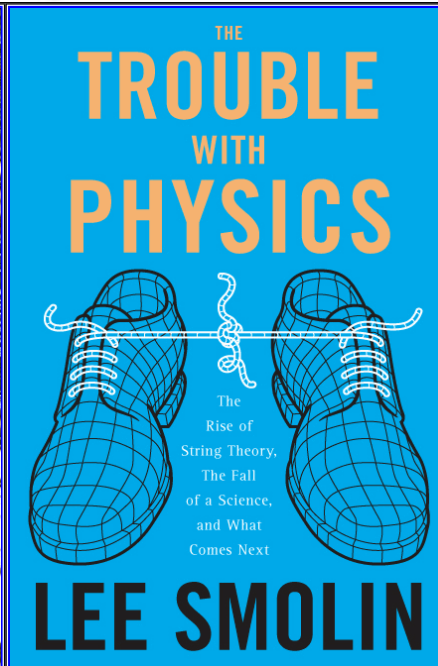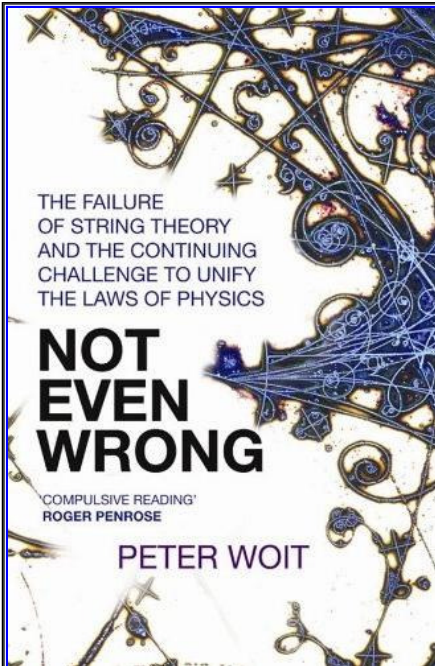'Science is the organized skepticism in the reliability of expert opinion.' - R. P. Feynman (quoted by Smolin, *The Trouble with Physics*, 2006, p. 307).

'Science *n.* The observation, identification, description, experimental investigation, and theoretical explanation of phenomena.' - www.answers.com

Quantum Field Theory

THE FAILURE OF STRING THEORY AND THE CONTINUING CHALLENGE TO UNIFY THE LAWS OF PHYSICS

NOT EVEN WRONG

'COMPULSIVE READING'
ROGER PENROSE

PETER WOIT

THE TROUBLE WITH PHYSICS

The Rise of String Theory, The Fall of a Science, and What Comes Next

LEE SMOLIN

Mainstream (M-) theory, i.e. 10-dimensional spin-2 graviton superstring as a surface or 'brane' on an 11-dimensional supergravity - a supersymmetric theory supposed to make charge strengths unify at the Planck scale - compactifies 6 speculative spatial dimensions into an unobserved small Calabi-Yau manifold with many unknown size and shape parameters (moduli), so there are 10^{500} distinguishable models of string theory, making it a vague theory (like the prediction that a coin may land either heads up or tails up, comprehensiveness takes away any useful predictivity!). The alleged empirical evidence for string theory is not particle physics (the Standard Model parameters) but *unobserved Planck scale unification and unobserved spin-2 graviton* speculation. Even the AdS/CFT correspondence conjectured in string theory is physically empty, since AdS (anti de Sitter space) requires a *negative* cosmological constant. So you can't evaluate the conformal **field** theory (CFT) of particles with AdS, because AdS isn't real spacetime! The strong nuclear force is like a negative (attractive) cosmological constant, so (like stretching elastic band models), AdS/CFT may model gluon/pion mediated interactions.
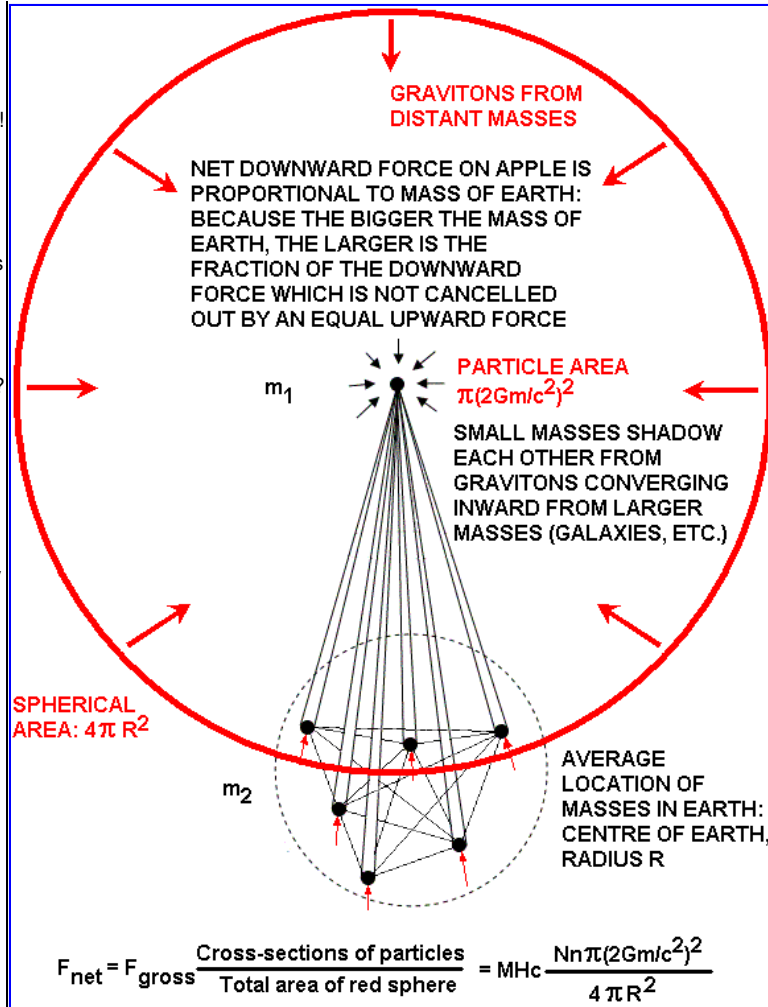
We're surrounded by immense visible, receding masses totalling $m = 3 \times 10^{52}$ kg ([the Hubble Space Telescope gives an estimate of stars in the observable universe of 9×10^{21} observable stars, with a mean mass assumed to be the solar mass of 2×10^{30} kg on the basis that the large population of dwarf stars balances out the population of stars whose mass is greater than the solar mass](); the source of this estimate is [page 5 of the NASA report linked here, so complain to NASA and the Hubble Space Telescope inventors if you don't like scientific facts, not me!]()), which are accelerating radially away from us at acceleration, $a = Hc = 7 \times 10^{-10}$ ms^{-2} (L. Smolin, *The Trouble With Physics*, Houghton Mifflin, N.Y.,

2006, p. 209), giving an outward effective force by Newton's 2nd law of about $F = ma = (3 \times 10^{52}) \times (7 \times 10^{-10}) = 2 \times 10^{43}$ Newtons!

By Newton's 3rd law of motion, every force has an equal and opposite reaction force, so there is an inward force towards us from distant receding masses of 2×10^{43} Newtons! What particles do we know of that can mediate such large forces? They act like spin-1 gauge boson radiation in causing gravity *by pushing relatively small masses (compared to the mass of the universe) together,* so should be called gravitons (gravity **field** quanta). Why apply Newton's old laws (first published on 5 July 1687) to the acceleration of the universe? Professor Feynman said:

'... we must take our concepts and extend them to places where they have not yet been checked.'

- R. P. Feynman *et al., Feynman Lectures on Physics, v. 3,* **Quantum Mechanics,** Addison-Wesley, 1965, c. 2, p. 9.

GRAVITONS FROM DISTANT MASSES

NET DOWNWARD FORCE ON APPLE IS PROPORTIONAL TO MASS OF EARTH: BECAUSE THE BIGGER THE MASS OF EARTH, THE LARGER IS THE FRACTION OF THE DOWNWARD FORCE WHICH IS NOT CANCELLED OUT BY AN EQUAL UPWARD FORCE

m_1

PARTICLE AREA $\pi(2Gm/c^2)^2$

SMALL MASSES SHADOW EACH OTHER FROM GRAVITONS CONVERGING INWARD FROM LARGER MASSES (GALAXIES, ETC.)

SPHERICAL AREA: $4\pi R^2$

m_2

AVERAGE LOCATION OF MASSES IN EARTH: CENTRE OF EARTH, RADIUS R

$$F_{net} = F_{gross} \frac{\text{Cross-sections of particles}}{\text{Total area of red sphere}} = MHc \frac{Nn\pi(2Gm/c^2)^2}{4\pi R^2}$$

QUANTUM GRAVITY - SPIN 1 GRAVITONS EXCHANGED WITH DISTANT MASS M CARRY INWARD REACTION FORCE (ACCORDING TO NEWTON'S 3RD LAW): F = Ma.

a = Hc = COSMOLOGICAL ACCELERATION OF UNIVERSE

Gross inward force on red sphere, $F_{gross} = Ma = MHc$

NET FORCE = TOTAL INWARD FORCE MULTIPLIED BY FRACTION OF THAT WHICH IS SHIELDED BY MASSES, PUSHING THEM TOGETHER

SMALL MASSES SHADOW EACH OTHER FROM GRAVITONS CONVERGING INWARD FROM LARGER MASSES (GALAXIES, ETC.)

GRAVITONS FROM DISTANT MASSES

m_1 MAN

m_2 ON m_1 SHADOW

R

EARTH

m_2

SPHERICAL AREA: $4\pi R^2$

PARTICLE AREA $\pi(2Gm/c^2)^2$

$$F_{net} = F_{gross} \frac{\text{Cross-sections of particles}}{\text{Total area of red sphere}}$$

$$= MHc \frac{Nn\pi(2Gm/c^2)^2}{4\pi R^2}$$

$$= \frac{(nm)(Nm)(MHG^2/c^3)}{R^2}$$

$$= m_1 m_2 G / R^2$$

Hence $G = MHG^2/c^3 = c^3/(MH)$

M = mass of universe ~ 3×10^{52} kg
n = number of fundamental particles of mass m in man,
N = number of fundamental particles of mass m in Earth,
H = Hubble parameter ~ 2×10^{-18} s^{-1}

$\pi(2Gm/c^2)^2$ = event horizon cross-sectional area of black hole of mass m

Time — General relativity: smooth curvature (field quanta are simply ignored) M_1 ... M_2 Space

Time — spin-2 gravitons M_1 ... M_2 Space

Time — Gravitons push masses toward one another — Receding masses M_1 ... M_2 Space

Correct model of quantum gravity, including exchange between all masses including those in the surrounding universe: gravitons are spin-1 gauge bosons, not spin-2.

Gravity
Mass + Mass +
Weak exchange of gravitons between small masses allows them to be pushed together by exchange with larger, distant masses (e.g., clusters of galaxies)

Dark energy
+ +
Where the masses are very large, they exchange gravitons strongly with each other and get pushed by the impacts and recoil forces; 'dark energy'.

False objections: (1) LeSage had a non-predictive version of this, which failed (so-what? Aristarchus had a solar system model before Copernicus, Lamarke had a failed evolution theory before Darwin); (2) if particles exist in the vacuum they would slow down and heat up the planets by impacting on them like a drag force (wrong, gravitons are off-shell virtual particles so they cannot heat up or slow matter when causing forces which are in an equilibrium!)

Accurate implications: gravitons are spin-1 not spin-2. So checkable predictions are possible and the Standard Model can be revised to incorporate gravity. Particle overlap is negligible because of the tiny black hole event horizon cross-section, so equivalence principle holds well.

QED. Compare the result illustrated for the **quantum** gravity force parameter, $G = c^3/(MH)$, to the empirical value obtained for Newtonan gravity experimentally (by measuring the gravitational force between two large lead balls using the twisting of a small fibre). See how close the results are! Feynman advocated investigating some kind of simple **quantum** gravity for low energy physics in his November 1965 second Messenger lecture, 'The Relation of Mathematics to Physics' and in his 1985 book *QED* he shows how the path amplitude exp(iS) in the path integral can be evaluated geometrically in a simple way for low energy physics like the refraction of light by glass, the **quantum** Coulomb force due to chaotic exchange of virtual photons between an orbital electron and its nucleus (the fact that the virtual photons are exchanged at random intervals is the reason why electrons don't travel in the smooth closed elliptical orbits of Bohr's classical physics, and is also the reason why **quantum** tunnelling is possible, because there is always a probability that fewer than average virtual photons will be exchanged during a brief particular time interval, so sometimes electrons will be randomly able to penetrate through the 'Coulomb barrier' of classical, non-**quantum field** theory) since of course by Euler's equation, the path amplitude exp(iS) = (cos S) + i(sin S). Feynman says in the second Messenger lecture (broadcast by the BBC in November 1964 and published in the 1965 book *The Character of Physical Law*:

'What does the planet do? Does it look at the sun, see how far away it is, and decide to calculate on its internal adding machine the inverse of the square of the distance, which tells it how much to move? This is certainly no explanation of the machinery of gravitation!'

Feynman then gives the mechanism whereby gravitons cause gravity by scattering off nuclei, but deliberately dismisses it when not bothering to distinguish between on-shell (real) particles and off-shell (virtual) particles, so when he says that gravitons would slow

down planets like real dust would (by being heated up), his objection would debunk spin-2 gravitons of string theory just as much as any other particle. In fact, virtual bosons don't steal energy when interacting with steadily moving charges (you get a net emission of real radiation and hence energy loss only when charges accelerate; if the accelerating charge is electric then this radiation is photons and if it is gravitational charge i.e. mass-energy, the radiation is gravitational waves, which are real particles carrying net energy and are related to gravitons like virtual photons are related to real photons: *the virtual particles are off-shell and the real particles are on-shell*). Feynman was author of *Feynman Lectures on Gravitation,* and wasn't ignorant that virtual particles (gauge bosons) don't behave like real particles! His objection to LeSage is only applicable for on-shell real particles as gravitons, not to gauge bosons. Gauge bosons or virtual radiations still impart momentum as proved by the Casimir force, which is experimentally substantiated. However, vacuum radiation phenomena never steals kinetic energy from moving bodies unless there is acceleration! Acceleration causes contraction of the body, which readjusts the exchange radiation (graviton) equilibrium so that when the acceleration ends, no further energy is lost. This is a fact of nature.

Feynman's 'objection' to any exchange radiation theory of gravitation in claiming that vacuum radiation would cause drag is obviously bunk; we know the vacuum radiation pushes plates together in the Casimir force without slowing down charged particles in the vacuum! We know that on-shell particles don't behave like off-shell particles! If his objection was valid, it would debunk all the Standard Model forces which rely on vacuum exchange radiations! It isn't valid. What Feynman was really doing was *popularizing the idea that some kind of simple mechanism might underly physics.* Feynman said:

'Suppose that in the world everywhere there are a lot of particles, flying through us at very high speed. They come equally in all directions – just shooting by – and once in a while they hit us in a bombardment. We, and the sun, are practically transparent for them, practically but not completely, and some of them hit. Look, then, at what would happen.

'If the sun were not there, particles would be bombarding the Earth from all sides, giving little impulses by the rattle, bang, bang of the few that hit. This will not shake the Earth in any particular direction [it will just make fundamental particles move chaotically, like Brownian motion, rather than along smooth classical geodesics], because there are as many coming from one side as from the other, from top as from bottom.

'However, when the sun is there the particles which are coming from that direction are partly absorbed [or reflected, as in the case of Yang-Mills gravitons, an exchange radiation!] by the sun, because some of them hit the sun and do not go through. Therefore, the number coming from the sun's direction towards the Earth is less than the number coming from the other sides, because they meet an obstacle, the sun. It is easy to see that the farther the sun is away, of all the possible directions in which particles can come, a smaller proportion of the particles are being taken out.

'The sun will appear smaller – in fact inversely as the square of the distance. Therefore there will be an impulse on the Earth towards the sun that varies inversely as the square of the distance. And this will be a result of large numbers of very simple operations, just hits, one after the other, from all directions. Therefore the strangeness of the mathematical relation will be very much reduced, because the fundamental operation is much simpler than calculating the inverse square of the distance. This design, with the particles bouncing, does the calculation.

'The only trouble with this scheme is that ... If the Earth is moving, more particles will hit it from in front than from behind. (If you are running in the rain, more rain hits you in the front of the face than in the back of the head, because you are running into the rain.) So, if the Earth is moving it is running into the particles coming towards it and away from the ones that are chasing it from behind. So more particles will hit it from the front than from the back, and there will be a force opposing any motion. This force would slow the Earth up in its orbit... So that is the end of that theory.

'"Well,' you say, 'it was a good one ... Maybe I could invent a better one.' Maybe you can, because nobody knows the ultimate. ...

'It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time. How can all that be going on in that tiny space? Why should it take an infinite amount of logic to figure out what one tiny piece of spacetime is going to do? So I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities.'

String theory predictions are *not analogous to* Wolfgang Pauli's prediction of neutrinos, which was indicated by the solid experimentally-based physical facts of energy conservation and the mean beta particle energy being only about 30% of the total mass-energy lost per typical beta decay event: Pauli made a checkable prediction, Fermi developed the beta decay theory and then invented the nuclear reactor which produced enough decay in the radioactive waste to provide a strong source of neutrinos (actually antineutrinos) which tested the theory because conservation principles had made precise predictions in advance, unlike string theory's 'heads I win, tails you lose' political-type, fiddled, endlessly adjustable, never-falsifiable pseudo-'predictions'. Contrary to false propaganda from certain incompetent string 'defenders', Pauli correctly predicted that neutrinos *are* experimentally checkable, in a 4 December 1930 letter to experimentalists: '... Dear Radioactives, test and judge.' (See footnote on p12 of this reference.)

'The one thing the journals do provide which the preprint database does not is the peer-review process. The main thing the journals are selling is the fact that what they publish has supposedly been carefully vetted by experts. The Bogdanov story shows that, at least for papers in **quantum** gravity in some journals [including the U.K. Institute of Physics journal *Classical and **Quantum** Gravity*], this vetting is no longer worth much. ... Why did referees in this case accept for publication such obviously incoherent nonsense? One reason is undoubtedly that many physicists do not willingly admit that they don't understand things.' - P. Woit, *Not Even Wrong,* Jonathan Cape, London, 2006, p. 223.

'Worst of all, superstring theory does not follow as a logical consequence of some appealing set of hypotheses about nature. Why, you may ask, do the string theorists insist that space is nine dimensional? Simply because string theory doesn't make sense in any other kind of space.' - Nobel Laureate Sheldon Glashow (quoted by Dr Peter Woit in *Not Even Wrong: The Failure of String Theory and the Continuing Challenge to Unify the Laws of Physics,* Jonathan Cape, London, 2006, p181).

'Actually, I would not even be prepared to call string theory a 'theory' ... Imagine that I give you a chair, while explaining that the legs are still missing, and that the seat, back and armrest will perhaps be delivered soon; whatever I did give you, can I still call it a chair?' - Nobel Laureate Gerard 't Hooft (quoted by Dr Peter Woit in *Not Even Wrong: The Failure of String Theory and the Continuing Challenge to Unify the Laws of Physics,* Jonathan Cape, London, 2006, p181).

'... I do feel strongly that this is nonsense! ... I think all this superstring stuff is crazy and is in the wrong direction. ... I don't like it that they're not calculating anything. I don't like that they don't check their ideas. I don't like that for anything that disagrees with an experiment, they cook up an explanation ... All these numbers [particle masses, etc.] ... have no explanations in these string theories - absolutely none!' – Richard P. Feynman, in Davies & Brown, 'Superstrings' 1988, at pages 194-195. (Quotation courtesy of Tony Smith.)

Tony Smith's CERN document server paper, EXT-2004-031, uses the Lie algebra E6 to avoid 1-1 boson-fermion supersymmetry: 'As usually formulated string theory works in 26 dimensions, but deals only with bosons … Superstring theory as usually formulated introduces fermions through a 1-1 supersymmetry between fermions and bosons, resulting in a reduction of spacetime dimensions from 26 to 10. The purpose of this paper is to construct … using the structure of E6 to build a string theory without 1-1 supersymmetry that nevertheless describes gravity and the Standard Model…' However, that research was censored off arXiv, apparently because mainstream string theorists are bigoted against 26-dimensional ideas since 10/11-dimensional M-theory was discovered in 1995. They don't exactly encourage alternatives, even within the general framework of string theory (26-dimensional bosonic string theory is similar to 10-dimensional superstring in having a 2-dimensional spacetime worldsheet, the difference is that conformal **field** theory requires 24 dimensions in the absense of supersymmetry and 8 dimensions if there is supersymmetry).

Worse, attempts to explain observed particle physics with string theory result in 10^{500} or more different vacuum states, each with its own set of particle physics. 10^{500} solutions is so many it eliminates falsifiability from string theory. This large number of solutions is named the 'cosmic landscape' because Professor Susskind claims that each solution exists in a different parallel universe, and when you plot the resulting vacuum 'cosmological constants' as a function of two variables, in string theory, you produce a landscape-like three dimensional graph. The reason for the immense 'cosmic landscape' is the fact that string theories only 'work' (i.e., satisfy the basic criteria for conformal **field** theory, CFT) in 10 or more dimensions, so the unobserved dimensions have to be 'compactified' by a Calabi-Yau manifold, which - conveniently - curls up the extra dimensions in to a small volume, explaining why nobody has ever observed any of them. In superstring theory, two dimensions (one space and one time) form a 'worldsheet' and another eight are required for the CFT of supersymmetric particle physics. Sadly, the Calabi-Yau manifold has many parameters (or moduli) describing size and shape of those unobserved conjectured extra dimensions which must have unknown values (since we can't observe them), so it is the immense number of possible combinations of these unknown parameters which make string theory fail to produce specific results, by producing too many results to ever rigorously evaluate, even given a supercomputer running for the age of the universe. The 10^{500} figure might not be right: the true figure might be infinity. String theory results depend on many things, e.g., how the moduli are 'stabilized' by 'Rube-Goldberg machines', monstrous constructions added to the theory just to stop string **field** properties from conflicting with existing physics! It's presumably hoped by Dr Witten, discoverer of a 10/11-dimensional superstring-supergravity unification called M-theory, that somehow a way will turn up to pick out the correct solution from the landscape and start making checkable predictions.

However, the best idea of how to go about this is to assume that cosmology is correctly modelled by the Lambda-CDM general relativity solution, which attributes the observed lack of gravitational deceleration in the universe to dark energy, represented by a small positive cosmological constant in general relativity **field** equations. Then you can try to evaluate parts of the landscape of solutions to string theory which have a suitably small positive cosmological constant. Unfortunately, general relativity does not include **quantum** gravity, and even the mainstream **quantum** gravity candidate of an attractive force mediated by spin-2 gravitons, implies that gravity should be weakened over vast distances due to redshift of gravitons exchanged between receding masses, which lowers the energy of the gravitons received in interactions and reduces the coupling constant for gravity. Thus, dark energy may be superfluous if **quantum** gravity is correct, so it is clear that string theory is really a belief system, a faith-based initiative, with no physics or science of any kind to support it. String theory produces endless research, and inspires new mathematical ideas, albeit less impressively than Ptolemy's universe, Maxwell's aether and Kelvin's vortex atom (e.g., the difficulties of solving Ptolemy's false epicycles inspired Indian and Arabic mathematicians to develop trigonometry and algebra in the dark ages), but this doesn't justify Ptolemy's earth-centred universe, Maxwell's mechanical aether, Kelvin's stable vortex atom, and string theory. Another problem of this stringy mainstream research is that it leads to so many speculative papers being published in physics journals that the media and the journals concentrate on strings, and generally either censor out or give less attention to alternative ideas. Even if many alternative theories are wrong, that may be less harmful to the health of physics than one massive mainstream endeavour that isn't even wrong...

Loop **quantum** gravity is an alternative to string theory: it is simply the idea of applying the path integrals of **quantum field** theory to quantize gravity by summing over interaction history graphs in a network (such as a Penrose spin network) which represents the **quantum** mechanical vacuum through which vector bosons such as gravitons are supposed to travel in a standard model-type, Yang-Mills, theory of gravitation. This summing of interaction graphs successfully allows a basic framework for general relativity to be obtained from **quantum** gravity. The model is not as speculative as string theory, which has been actively promoted in the media since 1985 despite opposition from people like Feynman because it fails to predict anything. Despite endless hype, string theory is now in a state called 'not even wrong', which is less objective than the *wrong* theories of caloric, phlogiston, aether, flat earth, and epicycles, which were theories that tried to model some *observed* phenomena of heat, combustion, electromagnetism, geography, and astronomy.

String theory fails because it postulates that 6 dimensions are compactified into unobservably small manifolds in particles; these 6 unobservable dimensions need about 100 parameters to describe them, and it turns out that there are 10^{500} or more configurations possible, each describing a different set of particles (different particles within any set arise from the different possible vibration modes or resonances of a given string). This makes it the vaguest, least falsifiable mainstream speculation ever: to make genuine predictions, the state of the extra unobserved 6-dimensions must be known, which means either building a particle accelerator the size of the galaxy and scattering particles to reveal their Planck scale nature, or eliminating the false 10^{500} guesses, which would take billions of years with supercomputers. But there is some experimental evidence that key stringy assumptions, e.g., spin-2 gravitons and supersymmetry, are false.

For supersymmetry, in the book *Not Even Wrong* (UK edition), Dr Woit explains on page 177 that - using the measured weak and electromagnetic forces - supersymmetry predicts the strong force incorrectly high by 10-15%, when the experimental data is accurate to a standard deviation of about 3%. Supersymmetry is also a disaster for increasing the number of Standard Model parameters (couping constants, masses, mixing angles, etc.) from 19 in the empirically based Standard Model to at least 125 parameters (mostly unknown!) for supersymmetry. Supersymmetry in string theory is 10 dimensional and involves a massive supersymmetric boson as a partner for every observed fermion, just in order to make the three Standard Model forces unify at the Planck scale (which is falsely assumed to be the grain size of the vacuum just because it was the smallest size dimensional analysis gave before the electron mass was known; the black hole radius for an electron is far smaller than the Planck size).

At first glance, this 10-dimensional superstring theory for supersymmetry contradicts the 11-dimensional supergravity ideas, but this 10/11 dimensional issue was conveniently explained or excused by Dr Witten in his 1995 M-theory, which shows that you can make the case that 10-dimensional superstrings are a brane (a kind of extra-dimensional equivalent surface) on 11-dimensional supergravity, similarly to how an *n* - 1 = 2 dimensional area is a surface (or mem-*brane*) on an *n* = 3 dimensional object (or *bulk*). 11-dimensional supergravity arises from the old Kaluza-Klein idea, which was debunked and corrected by Lunsford in a peer-reviewed, published paper - see International Journal of Theoretical Physics, Volume 43, Number 1, January 2004 , pp. 161-177(17) for publication details and here for a downloadable PDF file, which was immediately censored from arXiv which seems to be partly influenced in the relevant sections by a string professor at the University of Texas, Austin.

On the speculative nature of conjectures concerning spin-2 (attractive or 'suck') gravitons, Richard P. Feynman points out in *The Feynman Lectures on Gravitation*, page 30, that gravitons do not have to be spin-2, which has not been observed. Renormalization works in the standard model (for electromagnetic, weak nuclear and strong nuclear charges) because the gauge bosons which mediate force do not interact with themselves to create massive problems. This is not the case with the spin-2 gravitons in general. Spin-2 gravitons, because they have energy, should according to general relativity, themselves be sources for gravity on account of their energy, and should therefore themselves emit gravitons, which usually makes the renormalization technique ineffective for **quantum** gravity. String theory is supposed to dispense with renormalization problems because strings are not point particles but of Planck-length. The mainstream 11-dimensional supergravity theory includes a superpartner to the unobserved spin-2 graviton, called the spin-3/2 gravitino, which is just as unobserved and non-falsifiable as the spin-2 graviton. The reason is that this supersymmetric scheme gets rid of problems which the spin-2 graviton idea would lead to at unobservably high energy where gravity is speculated to unify with other forces into a single superforce.

So a supersymmetric partner for the spin-2 attractive graviton is postulated in mainstream supergravity to make the spin-2 graviton theory work by *cancelling out the unwanted effects of the grand unified theory speculations*. Hence, you have to add extra speculations to spin-2 gravitons just to cancel out the inconsistencies in the original speculation that all forces should have equal coupling constants (relative charges) at unobservably high energy. The inventing of new uncheckable speculations to cover up inconsistencies in old uncheckable speculations is not new. (It is reminiscent of the proud Emperor who used invisible cloaks to try to cover up his gullibility and shame, at the end of an 1837 Hans Christian Andersen fairytale.) *There is no experimental justification for the speculative mainstream spin-2 graviton scheme, nor any way to check it,* which is discussed in detail here (discussion of alleged reason for spin-2 gravitons) and here (the stringy landscape of 10^{500} spin-2 attractive graviton theories really do *suck* in more ways than one; spin-1 gravitons avert the normal problems of **quantum** gravity, and make proper predictions without inconsistencies).

Quantum field theory is the basis of the Standard Model of particle physics and is the best tested of all physical theories, more general in application and better tested within its range of application than the existing formulation of general relativity (which needs modification to include **quantum field** effects), describing all electromagnetic and nuclear phenomena. The Standard Model does not as yet include **quantum** gravity, so it is not a replacement yet for general relativity. However, the elements of **quantum** gravity may be obtained from an application of **quantum field** to a Penrose spin network model of spacetime (the path integral is the sum over all interaction graphs in the network, and this yields background independent general relativity). This approach, 'loop **quantum** gravity', is entirely different from that in string theory, which is based on building extra-dimensional speculation upon other speculations, e.g., the speculation that gravity is due to spin-2 gravitons (this is speculative is no experimental evidence for it). In loop **quantum** gravity, by contrast to string theory, the aim is merely to use **quantum field** theory to derive the framework of general relativity as simply as possible. Other problems in the Standard Model are related to understanding how electroweak symmetry is broken at low energy and how mass (gravitational charge) is acquired by some particles. There are several forms of speculated Higgs **field** which may rise to mass and electroweak symmetry breaking, but the details as yet unconfirmed by experiment (the Large Hadron Collider may do it). Moreover, there are questions about how the various parameters of the Standard Model are related, and the nature of fundamental particles (string theory is highly speculative, and there are other possibilities).

There are several excellent approaches to **quantum field** theory: at a popular level there is Wilczek's 12-page discussion of *Quantum Field Theory*, Dyson's *Advanced Quantum Mechanics* and the excellent approach by Alvarez-Gaume and Vazquez-Mozo, *Introductory Lectures on Quantum Field Theory*. A good mathematics compendium introducing, in a popular way, some of maths involved is Penrose's *Road to Reality* (Penrose's twistors inspired some concepts in an *Electronics World* article of April 2003). For a very brief (47 pages) yet more abstract or mathematical (formal) approach to **quantum field** theory, see for comparison Crewther's http://arxiv.org/abs/hep-th/9505152. For a slightly more 'stringy'-orientated approach, see Mark Srednicki's 608 pages textbook, via http://www.physics.ucsb.edu/~mark/qft.html, and there is also Zee's *Quantum Field Theory in a Nutshell* on Amazon to buy if you want something briefer but with that mainstream speculation (stringy) outlook.

Ryder's **Quantum Field** Theory also contains supersymmetry unification speculations and is available on Amazon here. Kaku has a book on the subject here, Weinberg has one here, Peskin and Schroeder's is here, while Einstein's scientific biographer, the physicist Pais, has a history of the subject here. Baez, Segal and Zhou have an algebraic **quantum field** theory approach available on http://math.ucr.edu/home/baez/bsz.html, while Dr Peter Woit has a link to handwritten **quantum field** theory lecture notes from Sidney Coleman's course which is widely recommended, here. For background on representation theory and the Standard Model see Woit's page here for maths background and also his detailed suggestion, http://arxiv.org/abs/hep-th/0206135. For some discussion of

quantum field theory equations without the interaction picture, polarization, or renormalization of charges due to a physical basis in pair production cutoffs at suitable energy scales, see Dr Chris Oakley's page http://www.cgoakley.demon.co.uk/qft/. Dr Chris Oakley assumes that Haag's theorem is true (it has been proved mathematically, but depends on certain postulates which physically may be incorrect), and tries to develop a model in which interaction effects (e.g., the exchange of gauge bosons between charges to produce forces) are interferences between free **field** states. Maybe this is a valid analogy which will throw light on things like **quantum** entanglement/Aspect results in **quantum** mechanics, but it doesn't seem to make checkable predictions easily for things already done well in the mainstream's interaction-based (Haag theorem ignoring) **quantum field** theory.

The ever humorous and good-natured Professor Warren Siegel has an 885 pages long free textbook, *Fields* http://arxiv.org/abs/hep-th/9912205, the first chapters of which consist of a very nice introduction to the technical mathematical background of experimentally validated **quantum field** theory (it also has chapters on speculative supersymmetry and speculative string theory toward the end).

Gerard 't Hooft has a brief (69 pages) review article, *The Conceptual Basis of **Quantum Field** Theory,* here, and Meinard Kuhlmann has an essay on it for the *Stanford Encyclopedia of Philosophy* here.

'In loop **quantum** gravity, the basic idea is to use the standard methods of **quantum** theory, but to change the choice of fundamental variables that one is working with. It is well known among mathematicians that *an alternative to thinking about geometry in terms of curvature fields at each point in a space is to instead think about the holonomy [whole rule] around loops in the space. The idea is that in a curved space, for any path that starts out somewhere and comes back to the same point (a loop), one can imagine moving along the path while carrying a set of vectors, and always keeping the new vectors parallel to older ones as one moves along. When one gets back to where one started and compares the vectors one has been carrying with the ones at the starting point, they will in general be related by a rotational transformation.* This rotational transformation is called the holonomy of the loop. It can be calculated for any loop, so the holonomy of a curved space is an assignment of rotations to all loops in the space.' - P. Woit, *Not Even Wrong,* Jonathan Cape, London, 2006, p189. (Emphasis added.)

'Plainly, there *are* different approaches to the five fundamental problems in physics.' – Lee Smolin, *The Trouble with Physics: The Rise of String Theory, The Fall of a Science, and What Comes Next*, Houghton Mifflin, New York, 2006, p254.

The major problem today seems to be that general relativity is fitted to the big bang *without* applying corrections for **quantum** gravity which are important for relativistic recession of gravitational charges (masses): the redshift of gravity causing gauge boson radiation reduces the gravitational coupling constant G, weakening long range gravitational effects on cosmological distance scales (i.e., between rapidly receding masses). This mechanism for a lack of gravitational deceleration of the universe on large scales (high redshifts) has counterparts even in alternative push-gravity graviton ideas, where gravity - and generally curvature of spacetime - is due to shielding of gravitons (in that case, the mechanism is more complicated, but the effect still occurs).

Professor Carlo Rovelli's **Quantum Gravity** is an excellent background text on loop **quantum** gravity, and is available in PDF format as an early draft version online at http://www.cpt.univ-mrs.fr/~rovelli/book.pdf and in the final published version from Amazon here. Professor Lee Smolin also has some excellent online lectures about loop **quantum** gravity at the Perimeter Institute site, here (you need to scroll down to 'Introduction to **Quantum** Gravity' in the left hand menu bar). Basically, Smolin explains that loop **quantum** gravity gets the Feynman path integral of **quantum field** theory by summing all interaction graphs of a Penrose spin network, which amounts to general relativity without a metric (i.e., background independent). Smolin also has an arXiv paper, *An Invitation to Loop **Quantum** Gravity*, here which contains a summary of the subject from the existing framework of mathematical theorems of special relevance to the more peripherial technical problems in **quantum field** theory and general relativity.

However, possibly the major future advantage of loop **quantum** gravity will be as a Yang-Mills **quantum** gravity framework, with the physical dynamics implied by gravity being caused by full cycles or complete loops of exchange radiation being exchanged between gravitational charges (masses) which are receding from one another as observed in the universe. There is a major difference between the chaotic space-time annihilation-creation massive loops which exist between the IR and UV cutoffs, i.e., within 1 fm distance from a particle core (due to chaotic loops of pair production/annihilation in **quantum** fields), and the more classical (general relativity and Maxwellian) force-causing exchange/vector radiation loops which occur *outside the 1 fm range of the IR cutoff energy* (i.e., at lower energy than the closest approach - by Coulomb scatter - of electrons in collisions with a kinetic energy similar to the rest mass-energy of the particles).

'It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time. How can all that be going on in that tiny space? Why should it take an infinite amount of logic to figure out what one tiny piece of spacetime is going to do? So I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities.' - R. P. Feynman, *The Character of Physical Law,* November 1964 Cornell Lectures, broadcast and published in 1965 by BBC, pp. 57-8.

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*Feynman is here referring to the physics of the infinite series of Feynman diagrams with corresponding terms in the perturbative expansion for interactions with virtual particles in the vacuum in **quantum field** theory:*

'Given any **quantum field** theory, one can construct its perturbative expansion and (if the theory can be renormalised), for anything we want to calculate, this expansion will give us an infinite sequence of terms. Each of these terms has a graphical representation called a Feynman diagram, and these diagrams get more and more complicated as one goes to higher and higher order terms in the perturbative expansion. There will be some ... 'coupling constant' ... related to the strength of the interactions, and each time we go to the next higher order in the expansion, the terms pick up an extra factor of the coupling constant. For the expansion to be at all useful, the terms must get smaller and smaller fast enough ... Whether or not this happens will depend on the value of the coupling constant.' - P. Woit, *Not Even Wrong,* Jonathan Cape, London, 2006, p. 182.

'For the last eighteen years particle theory has been dominated by a single approach to the unification of the Standard Model interactions and **quantum** gravity. This line of thought has hardened into a new orthodoxy that postulates an unknown fundamental supersymmetric theory involving strings and other degrees of freedom with characteristic scale around the Planck length. ... It is a striking fact that there is absolutely no evidence whatsoever for this complex and unattractive conjectural theory. There is not even a

serious proposal for what the dynamics of the fundamental 'M-theory' is supposed to be or any reason at all to believe that its dynamics would produce a vacuum state with the desired properties. The sole argument generally given to justify this picture of the world is that perturbative string theories have a massless spin two mode and thus could provide an explanation of gravity, if one ever managed to find an underlying theory for which perturbative string theory is the perturbative expansion.' – P. Woit, *Quantum Field Theory and Representation Theory: A Sketch* (2002), pp51-52.

'String theory has the remarkable property of predicting gravity.' - E. Witten (M-theory originator), *Physics Today,* April 1996.

'50 points for claiming you have a revolutionary theory but giving no concrete testable predictions.' - J. Baez (crackpot Index originator), comment about crackpot mainstream string 'theorists' on the *Not Even Wrong* weblog here.

'It has been said that more than 200 theories of gravitation have been put forward; but the most plausible of these have all had the defect that they lead nowhere and admit of no experimental test.' - Sir Arthur Eddington, *Space Time and Gravitation,* Cambridge University Press, 1921, p64. (Here is a link to checkable **quantum** gravity framework which made published predictions in 1996 which were confirmed by observations in 1998, but censored out due to the immensely loud noise generators in vacuous string theory.).

Last Updated: 27 September 2009. This page is under revision. Some older material is here.

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