WHY THERE CAN BE NO 'QUANTUM THEORY OF GRAVITY'.

By

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This paper sets out to refute the idea of a 'quantum theory of gravity' on the basis that the General Theory of Relativity accounts for gravity in terms of the curvature of space-time, rather than treating it as a force.

The achievement of Albert Einstein in formulating the Special (1905) and General (1916) Theories of Relativity[1,2] should have made clear to 20th and 21st Century physicists that gravity was not a force, like electromagnetism and the weak and strong nuclear interactions, but the manifestation of the curvature of space-time, as evinced by the acceleration of objects in the presence of a gravitational field (which is the same thing as curved space-time[3]).

This having been made clear, it should also have been clear that quantum mechanics did not apply to gravitation, and that all talk of a 'quantum theory of gravity' was nonsensical. The attempt to account for gravity as if it were an 'interaction', involving the exchange of 'virtual gravitons[4]' between particles,

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[1]Special Theory of Relativity: Einstein, A, 'On the Electrodynamics of Moving Bodies [*Zur Elektrodynamik bewegter Körper*]', ***Annalen der Physik* 17:891**, 30th June, 1905, English trans. http://www.fourmilab.ch/etexts/einstein/specrel/specrel.pdf; idem, 'Does the Inertia of a Body Depend Upon Its Energy Content? [*Ist die Trägheit eines Körpers von seinem Energiegehalt abhängig?*]', ***Annalen der Physik* 18:639**, 27th September, 1905, Eng. trans. http://www.fourmilab.ch/etexts/einstein/E_mc2/e_mc2.pdf.

[2]General Theory of Relativity: idem, 'The Foundation of the Generalised Theory of Relativity [*Die Grundlage der Allgemeinen Relativätstheorie*]', ***Annalen der Physik* 49(7):769-822**, accepted 20th March 1916, Eng. trans. by S.N. Bose, http://en.wikisource.org/wiki/The_Foundation_of_the_Generalised_Theory_of_Relativity.

[3]Einstein's former teacher Hermann Minkowski (1864-1909) also made a major contribution to the concept of four-dimensional space-time, as shown by his Address ('Space and Time' [*Raum und Zeit*]) to the 80th Assembly of German Natural Scientists and Physicians (21st September, 1908), which was an essential prerequisite of the General Theory. Eng. trans., see: http://en.wikisource.org/wiki/Space_and_Time_(Wikisource). The idea of *curved* space derives from 19th century mathematicians such as János Bolyai (1802-60), Nikolai Lobachevsky (1792-1856) and Bernhard Riemann (1826-66).

[4]Gravitons, if they existed, would be massless particles ('bosons') with zero charge and spin 2, and would travel at the speed of light. None have been detected. See: http://www.fnal.gov/pub/today/archive/archive_2012/today12-10-19_NutshellReadMore.html.

by analogy with the exchange of virtual photons[5] that takes place between electrically charged particles in electromagnetism, is doomed to failure. Quantum mechanical laws, of which the Heisenberg Uncertainty Principle[6] is the most important, do not apply, either to gravity or to space-time[7].

The waters were muddied, unfortunately, principally by Einstein himself, who sought to formulate a unified field theory which would account for all the forces of nature in terms of geometry (effectively reducing physics to geometry). He was aided in this by Theodor Kaluza[8] and again by Oskar Klein[9], who noted that the addition of a fifth dimension (suitably 'compactified', in Klein's formulation, i.e., rolled up into a very small size) to

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[5]By contrast, the quantum theory of electromagnetism is the most accurate physical theory we possess. The theory's prediction of a quantity termed the 'electron spin g-factor' (http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/lamb.html) compared to its experimentally determined value has been described by the late Richard Feynman (1918-88) as an achievement similar to measuring the distance from New York to Los Angeles to within the width of a human hair (in *QED – The Strange Theory of Light and Matter*, 1985).

[6]The Principle, formulated by Werner Heisenberg (1901-76) in 1927 in his paper, 'On the Visualisable Content of Quantum Theoretical Kinematics and Mechanics [*Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik*]', ***Zeitschrift für Physik*** **43(3-4):172-98**, Eng. trans. by NASA, http://ia600505.us.archive.org/19/items/nasa_techdoc_19840008978/19840008978.pdf, that the product of the uncertainties in the positions and momenta of quantum particles, or alternatively, the product of their energies and lifetimes, cannot be less than $\hbar/2$, or $h/4\pi$, where h is Planck's constant.

[7]Theories of quantum space-time, such as loop quantum gravity (http://en.wikipedia.org/wiki/Loop_Quantum_Gravity), try to present a picture of space-time where it is granular at ultra-sub-microscopic (Planck) scale, i.e., where the length is equal to the Planck length = $(G\hbar/c^3)^{½} = \ell_P$ (~1.6162×10^{-35}m) and times are of the order of the Planck time = ℓ_P/c (5.391×10^{-44}s). There is, however, no need for such a theory: gravity does not entail the exchange of virtual particles, or the transmission of any form of energy. It is not a force; it simply entails objects following what would otherwise be straight lines in Euclidean, or 'flat', space (technically, in Riemannian or hyperbolic space, *geodesics* – see http://en.wikipedia.org/wiki/Geodesics_in_general_relativity), were it not for space-time curvature. There is no reason to suppose that space-time is not continuous and infinitely divisible, and the Principle of Occam's Razor (*entia non sunt multiplicandur quaerens necessitatem*) would support this contention (see: http://rationalwiki.org/wiki/Occam's_razor).

[8]See biography at: http://www-groups.dcs.st-and.ac.uk/history/Biographies/Kaluza.html.

[9]Oskar Klein (1894-1977), see biography here: http://www-history.mcs.st-andrews.ac.uk/Biographies/Klein_Oskar.html, produced a more realistic version of Kaluza-Klein theory than Kaluza himself had done. Both had depended on the earlier work of Gunnar Nordström (http://en.wikipedia.org/wiki/Gunnar_Nordstr%C3%B6m). For a non-technical account of the theory, see: http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Kaluza%E2%80%93Klein_theory.html.

the field equations of the General Theory allowed it to account for James Clerk Maxwell's[10] theory of electromagnetism, as well as gravity.

The problem with this, of course, is that Maxwell's theory, though perfectly adequate for normal purposes, is a *classical*[11] theory. At the quantum scale, it has to be replaced by Quantum Electro-Dynamics (QED). No formulation of Kaluza-Klein theory has succeeded in uniting the General Theory with QED, let alone with Electroweak Theory[12], which unites electromagnetism with the weak nuclear interaction, or any of the 'Grand Unified Theories'[13][14], which include the strong nuclear interaction.

For Isaac Newton, writing in the *Principia*[15], there could be no doubt that gravity was a force, acting between massive bodies instantaneously at a

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[10]The Scottish physicist James Clerk Maxwell (1831-79) published a set of field equations describing this phenomenon in 'A Dynamical Theory of the Electromagnetic Field', ***Philosophical Transactions of the Royal Society of London*** **155:459-512**, received 27th October, 1864; read 8th December, 1864; publ. 1st January, 1865, doi: 10.1098/rstl.1865.0008, http://upload.wikimedia.org/wikipedia/commons/1/19/A_Dynamical_Theory_of_the_Electromagnetic_Field.pdf.

[11]'Classical' in the sense that it does not take account of quantum mechanical laws such as the Uncertainty Principle.

[12]'Electroweak' theory is the theory developed by Abdus Salam, Sheldon Glashow and Steven Weinberg in the 1960s and early '70s that unified the electromagnetic and weak nuclear interactions and was vindicated with the discovery of weak neutral currents in 1974 and of the W^+, W^- and Z^0 particles in 1983. The three theoreticians shared the Nobel Prize for Physics for their work on the theory in 1979.

[13]A Grand Unified Theory, or 'GUT', is one which attempts to unify the electroweak interaction with the strong nuclear interaction. Most of the proposed theories have major problems, such as predictions of magnetic monopoles and proton decay, with proton lifetimes that have been refuted by observational evidence. One great hope is the idea of 'supersymmetry', whereby all leptons, i.e., particles with half-integral spin, would have bosonic (integral spin) counterparts, and *vice versa*. A recent result from the Large Hadron Collider involving B_s mesons (which are composed of a bottom anti-quark and a strange quark) failed to show any evidence of supersymmetric particles, or 'sparticles'. For a non-technical account, see: http://www.nature.com/news/truant-particles-turn-the-screw-on-supersymmetry-1.11855.

[14]The Standard Model of Particle Physics (http://home.web.cern.ch/about/physics/standard-model), which has been vindicated by the confirmation of the existence of the Higgs boson (http://en.wikipedia.org/wiki/Higgs_boson) at the Large Hadron Collider is *not* a unified theory of particles and fields. The nearest unified (i.e., unifying electromagnetism with the strong and weak nuclear interactions) equivalent of it is the Minimal Supersymmetric Standard Model (http://en.wikipedia.org/wiki/Minimal_Supersymmetric_Standard_Model), or MSSM, but this postulates the existence of 'gravity mediated supersymmetry breaking', which would involve 'gravitons' and their supposed fermionic super-partners, 'gravitinos'. In other words, this theory suffers from the same fundamental intellectual error as all the other theories that are based on the idea of gravity as a force.

[15]The *Philosophiae Naturalis Principia Mathematica* ['Mathematical Principles of Natural Philosophy'], Latin ed. first published 5th July 1687, 1st English trans. by Andrew Motte, publ. 1729. See first American ed., revised by N.W. Chittenden, 1846,

distance[16], the force being (as we know) directly proportional to the product of the masses of the bodies, and inversely proportional to the square of the distance between them. For both Newton and Einstein, the Principle of Equivalence[17], which states that inertial mass – a body's resistance to acceleration, or change in its state of rest or uniform rectilinear motion – and gravitational mass are equivalent, is essential. However, Einstein rejected Newton's concept of instantaneous action at a distance, knowing (for one thing) that nothing physical (force, entity, signal, whatever) could exceed the speed of light. Furthermore, the whole idea of 'action at a distance' appeared to him, along with his mentor Ernst Mach[18], to be mystical nonsense.

Thus we have the familiar formulation of the so-called 'rubber-sheet'[19] conception of space-time. Furthermore, we also have a view of gravity as being like inertia, and inertial pseudo- or quasi-forces such as the familiar centrifugal and centripetal ones. When a body that is not subject to any external force, and is therefore obeying Newton's First Law of Motion, enters the gravitational field of a star (say), it appears to an observer to undergo an acceleration towards the star, and thus to be affected by a force, whereas in fact it is simply

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http://ia600300.us.archive.org/8/items/newtonspmathema00newtrich/newtonspmathema00newtrich.pdf.

[16]In fact, Newton seemed to face both ways on the issue of the existence of action at a distance, on the one hand vehemently denying its existence (http://plato.stanford.edu/entries/newton-philosophy/#ActDis), in a letter written in 1693 to the Rev Richard Bentley (1662-1742), and on the other producing a theory of gravity which absolutely requires it.

[17]The Principle of Equivalence was demonstrated by Newton, as Einstein pointed out: inertial mass × acceleration due to gravity = intensity of the gravitational field × gravitational mass. For someone standing on the surface of the Earth, the acceleration due to gravity is ~9.8 ms^{-2}. The intensity of the gravitational field = GM/r^2, where G is the Newtonian gravitational constant, ~6.67×10^{-11} Nm^2 kg^{-2}, M is the mass of the Earth (5.97219×10^{24} kg) and r the radius of the Earth (treating the Earth as a perfect sphere), 6,378,000 m, = 9.79243 ms^{-2}, which is about right. See: http://en.wikipedia.org/wiki/Equivalence_principle.

[18]Ernst Mach (1838-1916) was an empiricist and positivist, whose eponymous Principle (or Conjecture), enunciated in his *The Science of Mechanics: [a] Critical and Historical Exposition of its Principles* (1893), suggests that the inertia of a body depends, not on absolute space, as Newton contended, with his description of his 'bucket' experiment (see: http://www-history.mcs.st-and.ac.uk/PrintHT/Newton_bucket.html), but on its relationship to the 'fixed stars' and an influence of some kind kind emanating from distant matter (see: http://scienceworld.wolfram.com/physics/MachsPrinciple.html). This, however, seems every bit as mystical as the notion of 'action-at-a-distance', about which Einstein was to be so scornful in the context of quantum mechanics, and specifically quantum entanglement, referring to it, in a letter to Max Born written on 3rd March 1947, as '*spukhafte Fernwirkung*' – 'spooky action-at-a-distance'.

[19]Thus referred to because local space-time is depicted, analogously, precisely as if it were a 'rubber sheet', being 'bent', or curved, by the presence of mass-energy. The more mass-energy present in a given region of space-time, the greater the local space-time curvature, and the stronger the local gravitational field.

continuing to follow the equivalent of a straight line – a geodesic – in curved space-time.

It seems that nature is resisting all our attempts to create a simplified, reductionist and unified picture of her. We should rejoice in her untidiness and recalcitrance. It is truly humbling, and a reminder that we are not gods, and nor should we act like them. Less *hubris* is indeed required on all our parts, and rather more in the way of *sophrosunē*. The equation Einstein published in his second paper on the Special Theory of Relativity in 1905, $E = mc^2$, was crucial to the development of the atomic bomb in 1945. To quote T.S. Eliot's poem, *Gerontion* (1919/20), 'After such knowledge, what forgiveness?' It is simply not possible, or even desirable, for us, as it were, to put that genie back in its bottle, but the example should be a salutory lesson that knowledge represents danger as well as power.

As for the 'quantum theory of gravity', that clearly represents a wasted and misdirected intellectual effort that would be better devoted to other and more useful and fruitful endeavours. There is no intrinsic reason why nature's forces *should* be unified – we are fortunate that two of them are – and gravity isn't a force, in any event.

Why should physicists, and the physics community as a whole, persist in regarding gravity as if it were a force, even though it is freely acknowledged by many, if not most, of them[20] that it is not? This is a mystery that cannot be solved without straying into the realms of psychology and sociology, and is beyond the scope of the present work.

[20]See, for example, http://curious.astro.cornell.edu/relativity.php.