# Bundles of nothingness: Unravelling the zero-dimensional particle premise of fundamental physics

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***Abstract***

*The conventional conceptual framework for fundamental physics is built on a tacit construct: the premise of particles being zero-dimensional (0-D) points. There has never been a viable alternative to this, and the Bell-type inequalities preclude large classes of alternative designs with hidden variables. Although they do not absolutely preclude the possibility of particles having non-local hidden-variable (NLHV) designs, there is the additional difficulty of finding a solution within the very small freedom permitted by the constraints. Nonetheless we show that it is possible to find such a design. We propose the internal structures and discrete field structures of this 'cordus' particule, and the causal relationships for the behaviour of the system. This design is shown to have high conceptual fitness to explain a variety of fundamental phenomena in a logically consistent way. It provides insights into the fundamentals of matter, force, energy and time. It offers novel explanations to long-standing enigmas and suggests that a reconceptualisation of fundamental physics is feasible. We thus show that the 0-D point premise can be challenged, and is likely to have profound consequences for physics when it falls.*

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*'somewhere in our doctrine is hidden a concept, unjustified by experience, which we must eliminate to open up the road.'*

**Max Born (1954)**

Closing statement of his Nobel lecture

## The point construct

The history of fundamental physics is convoluted. Theories come and go, all chasing after an answer to the fundamental question, 'W*hat is reality made of?'* We say that everything is made up of particles. Well, what are particles? Our best theory of this foundational area is provided by quantum mechanics (QM), which insists they are zero dimensional (0-D) points. Mere bundles of nothingness containing energy.

The quantitative machinery of QM works incomparably well, but there are issues. QM does not scale up to the macroscopic level, and is itself unable

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to explain why. Gravitation has proved problematic to integrate into the framework. Also, QM's qualitative descriptions tend to weirdness. The usual explanation sidesteps the criticism by asserting that the probabilistic behaviour of the particle is simply the unquestionable reality. Perhaps that's fine if all you want to do is calculate things, but it is dissatisfying as an explanatory response.

The fact that QM does not fully describe physical reality suggests that it may be a mathematical approximation to a deeper physics that is yet to be discovered. In this paper we show that the issue is a logical one. We identify a crucial foundational premise of physics, identify its flaws, suggest a replacement construct, and run the thought-experiment to see what new physics comes into view.

## An idea

The whole conceptual framework of QM is built on the premise that particles of matter and light are zero-dimensional (0-D) points. Hence the conceptual treatment of quanta, particles, and virtual particles. The premise is implicit in the mathematical treatment, resulting in the Schrödinger equation. It provides the explicit rationale for the empirical approach of building particle colliders, and the framework for interpreting those results. It forms the paradigm within which new theories are conceptualised, e.g. the gluons of QCD, Higgs boson.

Quantum mechanics accepts that point particles have properties, including spin, momentum, and charge. However these are treated as *intrinsic* properties devoid of any deeper physical basis. Our criticism is that the QM construct of particle is overloaded. It fails the test of requisite variability: QM expects its particle to display more variables than it has physical features. '*What if we have got this fundamental premise wrong*? *What if particles had internal structures?*' We are not the first to ask, but here we hit a barrier: Bell's Theorem.

## Bell-type inequalities

There is a general opposition to the idea that particles could have internal physical substructures. The Bell-type inequalities are mathematical prohibitions against large classes of solutions involving 'hidden-variables' (HV).

Historically this arose as a counterpoint to the Einstein–Podolsky–Rosen (EPR) criticism that 'the description of reality as given by a wave function is not complete' [1].

Bell then showed that faster-than-light cause-and-effect (superluminal causality) could not be explained by initially encoding the two entangled particles with some 'hidden variable' before they were separated [2]. Bell's theorem states either superluminal entanglement or locality exists, not both.[a] Since entanglement is observed, the logical conclusion is that locality is false. This, of course, implies that no HV theory that relies on locality can ever successfully explain entanglement experiments. It is usually interpreted as meaning that particles cannot have internal structure.

However this is paradoxical because physics otherwise expects locality and local realism to apply. Objects and even small particles <u>do</u> seem to be only influenced by the pre-existing values of the fields or effects at that particular point. So when the entanglement results suggest that local realism fails, then that creates an incongruity because it is not a 'reasonable definition of reality' [1].

However Bell's theorem only limits *local* hidden variable solutions, not *non-local* hidden-variable (NLHV) theories. This is not contentious, though often overlooked. Even so, there is little confidence in the feasibility of NLHV solutions. The only extant non-local theory of any substance is the de Broglie-Bohm pilot wave theory [3-5]. This proposes that position and momentum are hidden variables, and the wave-function guides the moving particles down trajectories. It is primarily a solution for the double-slit device, but has not progressed much since its conception in 1925. The theory has its own difficulties, particularly of physical interpretation. As regards other NLHN theories, the whole class of 'crypto-nonlocal' theories, where the particles are independent to each other, seem precluded by the Leggett inequalities [3]. Other attempts have sought to add additional non-local variables, often piecemeal, but these too have failed [4] [5].

The desired attributes of a complete NLHV solution are:

(a) Theoretical validation: It will need to overcome the many existing constraints against whole classes of solutions. It could do this by *proving* that a class of HV solutions was *not* precluded, or it could *falsify* the existing inequalities by demonstrating a single case of a workable solution.

(b) Conceptual integrity: It will need to decide what variables to internalise, and provide a functionally coherent conceptual framework for them.

(c) Identify sub-structures: It will need to propose physical substructures to carry the internal variables, and provide a natural explanation for these, i.e. provide form to support the function.

(d) Causal model: It will need to propose causal relationships whereby the external evidenced behaviours of the particle are generated by internal mechanisms. These should be testable.

(e) Epistemic integration: It will need to subsume the mathematical models of QM, electromagnetic wave theory, and gravitation.

(f) Deeper insights: Its causal model will need to provide deeper insights that are inaccessible to the existing conceptual frameworks, and thereby move fundamental physics forwards.

None of the above specification has been achieved by any current NLHV model. There is no proof that NLHV solutions are even possible in principle, and there are no models that are able to predict the physical substructures or explain how the externally observed causality arises. The majority position interprets the evidence as disfavouring NLHV models. NLHV theories are in bad shape and would seem doomed.

However there is still hope, since the validity of the Bell-type exclusions is questionable [6, 7]. The issue concerns the ambiguity of the terms *locality*, *realism*, and *local realism,* the question of which apply in the situation, and how to represent them mathematically. Consequently is possible that what is proved in the theorems is merely a consequence of the tacit premises that the theorist initially brings to the problem. So it may be premature to preclude NLHV solutions [7].

Broad classes of solutions have already been excluded, so the solution space, if it exists at all, must be tiny. It will also be an odd solution, since it is generally recognised, even by detractors, that any non-local model of hidden-variables would have to be highly counterintuitive [5].

## A Design approach

Perhaps we have been going about it the wrong way. If the mathematical approach cannot conclusively prove (or disprove) the feasibility of NLHV solutions, then the other option is to falsify the Bell-type inequalities by producing a NLHV solution ex nihilo. But how?

One method that is sufficiently radical to have a chance of achieving this is engineering design, with its lateral thinking problem-solving methods. Design ignores premises and systematically applies creativity to anticipate what physical structures are sufficient to provide the requisite functionality.

Our design starts with that suspicious 0-D point, and progressively teases out the physical features required to explain the known functionality of particles.[b] We start with the weirdest experiment: the double-slit. Our logic runs like this: '*What if particles are not 0-D points, but linear structures with two ends?*' That has potential for explaining the photon path dilemmas. We'll call these 'cordus particules' (from the Latin for *cord).* We use the French *particule* (with the extra 'u') to describe this structure, thus signalling that it is a substitute concept for 'particle' but also profoundly different.

But what about the solid material between the slits? *'What if the ends were joined by a fibril that did not react with matter?'* Fine, that would solve the slit problem, but there are still the fringes to explain. '*What if the ends gave off discrete field pulses that interacted with the gap material?'* Yes, but there is still entanglement to consider. '*What if the fibril provided superluminal coordination between the ends?'* That could work. '*Does this satisfy Bell's inequality?*' Yes, since the variables are distributed over space. This is starting to look like it could have interesting implications.

Continuing this line of thinking results in a concept for the specific internal sub-structures, and how those structures would cause the observed phenomena. We call this thought experiment the 'Cordus conjecture'.

## Cordus conjecture

The Cordus conjecture [8] proposes that every particule has two reactive ends, which are a small finite distance apart (span), and each behave like a particle in their interaction with the external environment. A 'fibril' joins the reactive ends and is a persistent and dynamic structure but does not interact with matter. It provides instantaneous connectivity and synchronicity between the two reactive ends. Hence it is a non-local solution: the cordus is affected by more than the fields at its nominal centre point. The reactive ends are energised (typically in turn) at a frequency. The reactive ends emit one or more field lines (hyperfine fibrils or hyff) into space, and when the reactive end is energised it sends a transient force pulse (hyffon) outwards along the hyff curve. This makes for a field of discrete elements. Various features of the hyff and hyffon carry the electrostatic field, magnetism, and gravitation simultaneously. In this model the photon has a single radial hyff which it periodically extends and withdraws. By comparison all massy particules have permanent hyff (including neutral particules like the neutron). Electric charge is carried at 1/3 charge per hyff, so the electron has three hyff, arranged orthogonally, hence hyff emission directions (HEDs). The HEDs are comparable to colour in QCD. The basic cordus structures of the photon and electron are shown in Figure 1.

The hyff around massy particules compete for emission directions, and may synchronise their emissions to access those spaces. Thus there is an element of mutual negotiation, between interacting particules, based on shared geometric timing constraints, and this is proposed as the mechanism for the strong force.

## Does this work?

What we have achieved here is an NLHV solution. But is the idea any better than QM? Well, QM gives a very good mathematical explanation of particle behaviour, but nobody is quite sure what it means in a physical, conceptual sense. So let's explore the Cordus idea further, and see if it actually works.

*Entanglement*

Applied to entanglement, Cordus suggests that the cords of two photons lock onto each other and become synchronised through their discrete field structures, such that changes to the one affect the other. The photons are subsequently stretched so that the reactive ends are far apart. The fibrils retain their ability to communicate instantly. Changing one reactive end at one site therefore changes the other reactive end and also the second particule, and that change can be immediately observed at the other site, hence entanglement.

*Superposition*

The QM concept of superposition is that a particle exists simultaneously in all its possible states, including multiple places at once, but collapses to one of those when measured. We propose something superficially similar, that the two reactive ends of a particule energise and de-energise at a frequency, and thereby maintain two locations of existence. The similarities end there. The deeper reality, according to Cordus, is fundamentally not probabilistic but deterministic.

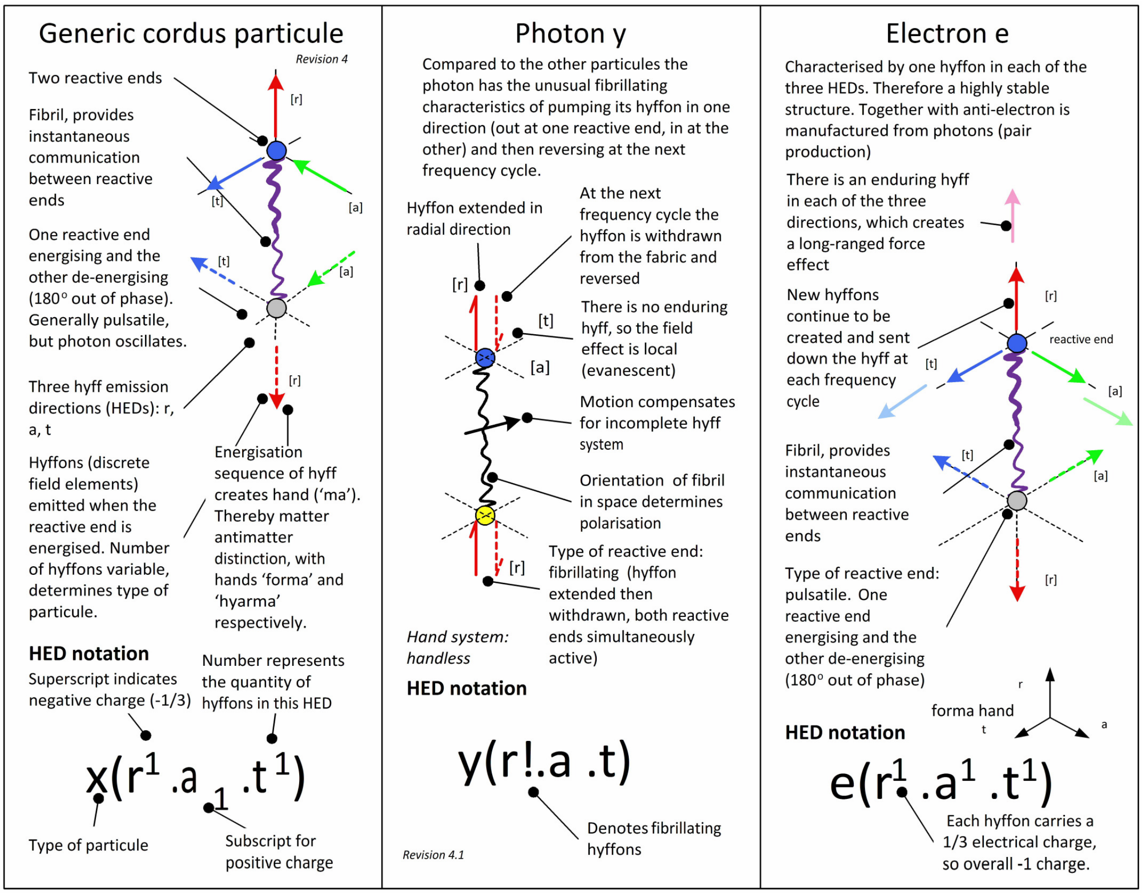


*Figure 1: Cordus model for the internal structure of the photon, and electron. Main structural components are the fibril, two reactive ends, and the discrete field elements (hyffons). It is the number and nature of the hyffons that determines the externalised behaviour of the particule. This is because these hyffons interact with those of other external particules and forces result. Note that the fibril provides instantaneous coordination between the two reactive ends, and is therefore superluminal. Hence Cordus is a non-local hidden variable solution.*

From the Cordus perspective the probabilities of a particule being in a particular location arise simply as the cutting points on the frequency when the experiment was stopped. The deeper mechanics are too fast to be represented in the formulism of QM, and therefore appear as stochastic variables. Thus superposition becomes a mathematical representation of the uncertain in average *position* of the two reactive ends.

Thus we reject QM's *temporal* form of superposition. The two reactive ends cannot take independent future states: the same fibril that provides superluminal entanglement also keeps them in the same reality and time. Therefore Cordus contrasts with the Copenhagen and many-worlds interpretations.

*Locality*

Locality fails. In its place we propose a Principle of Wider Locality, that a particule is affected by all the space to which its field structures (hyff) have access, and the discrete fields in its local surroundings. Further, that hyff have access to spaces beyond the reactive ends. Hence the Aharonov–Bohm effect. Cordus also explains why locality is generally not a bad approximation. This is because the external hyff fields are generally reasonably homogeneous in density, and the particule is usually of small span such that the effects are not generally visible. So *apparent locality* applies in most situations, especially when only the macroscopic behaviour of the particule is being considered. The implication is that locality is generally a sufficient approximation at the macroscopic level of particles, but not at finer scales or the contrived situation of entangled photons.

*Local realism also fails*

Our Cordus model does accept local realism to some extent: that properties exist before they are measured. There is an underlying determinism in the way that a cordus particule alternates its energy between its two reactive ends. However the act of measurement imposes external discrete fields and thereby affects the system being measured. Local realism is therefore highly conditional on invasiveness of the measurement method, i.e. contextual. Therefore we support the *pre-existing properties* concept of local realism, but not the *independence of observation*, and suggest it would be more helpful to disaggregate the two concepts.

*Wave-particle duality*

In wave-particle duality light goes through both paths in the double-slit experiment, and forms fringes behind. The surprise is that a single photon does likewise. The cordus explanation is: one reactive end of the particule goes through each slit > in passage the discrete fields are disturbed by the opaque edge of the gap > this causes the span of the entire photon to widen in discrete increments > hence the fringes > the first reactive end to reach the backplane collapses the entire photon at that location. So we provide a conceptual resolution to wave particle duality, by suggesting that light is neither a wave nor a particle, but rather a cordus particule that appears as a wave or a 0-D particle depending on how the observation is made [9]. We have also shown that Cordus gives new derivations for critical angle, Snell's law, and Brewster's angle, thereby demonstrating the fitness of the Cordus concept to both 'particle' trajectory problems and optical 'wave' situations.

*Parity violation*

One of the paradoxes of physics is why parity is violated. Parity refers to the expected symmetry of behaviour (e.g. equal decay or reaction rates) for a particle and its mirror structure (spatial inversion). The problem is that while parity is conserved for the electromagnetic and strong interactions, experiments show it is violated for the weak decay. Combining parity (P) and charge (C) symmetry results in CP-symmetry, but that too is violated in kaons. A *reason* for CP violation can now be offered: the cordus particule has a finite span (the geometric distance between the two reactive ends) and the discrete fields at each end have a direction (charge) and hand (matter-antimatter differentiation) that is consistent for both reactive ends of any one particule. The two reactive ends are not energised simultaneously (except for the photon and even then in opposite directions). Thus a cordus particule is not symmetrical: mirroring it does not result in an identical particule. This also explains why the CP violation only occurs at small scales: because this is the level at which the span becomes significant.[c] By comparison the 0-D point premise does not permit construction of a handed co-ordinate system.

*Coherence*

Coherence is understood in QM as the ability for particles to interfere, even one with itself. It involves the formation of dependencies between the particles, either by the correlation of a number of variables (spatial), or the temporal preservation of dependencies over time (temporal). QM uses coherence to explain constructive and destructive interference of photons, hence fringes. Nonetheless it is difficult for QM to give a physical interpretation of coherence. However a physical interpretation is readily available from Cordus: Coherence is when all the particules are assembled such that they provide mutual preservation of the de-energised locations of each other's reactive ends, and have synchronised frequencies. For photons in light beams, where the bonds between them are weak, the coherence is temporal. In superfluidity and superconductivity the coherence is substantial. Cordus explains the strange solid-body rotation of superfluids as arising from discrete fields that resist the shear force, and therefore maintain rigidity of the fluid. When the speed is too high, the bowl spins but the fluid stays still, explained by the need to preserve orientation of particules and hence avoid velocity gradients with radius through the fluid. Other properties of these states, including the quantum vortices, and rapid heat conduction, are also explainable in terms of a network of linked particules.

*QM's scaling problem*

Surprisingly, for a theory that applies so well to the particle level, QM does not apply to reality at our macroscopic level of existence. Superposition of location is only evident in particles and some microscopic objects of pure composition, cooled to close to absolute zero temperature, or momentarily in warmer objects. QM suggests should it should be attainable in larger and warmer objects, but this has not occurred. QM cannot identify why there should be a boundary, nor where it would be. This is a particularly serious issue for cosmology. The Cordus explanation is that QM does not scale up because macroscopic objects are decoherent. Cordus anticipates three mechanisms. First, a coherent material cannot accept gross internal shear, hence no internal mechanics or living physiology can be coherent. Second, higher temperatures lead to decoherence because phonons disturb the stability of the ordered arrangement of particules, hence internal thermodynamic processes must be benign. Third, more complex assemblies of matter are harder to put into coherence, due to the number of particules in the assembly, their geometric complexity, and inhomogeneity of composition. This model predicts that coherence is already unachievable at ambient temperature for small metal grains, mineral crystals, and cell organelles. Thus warm macroscopic objects and living creatures cannot be put into coherence or superposition. However there is predicted to be no problem with having coherent domains within a decoherent body, e.g. rapid electron transport across molecules within biological systems.

*Schrödinger's Cat*

Schrödinger's Cat is a QM thought experiment about a cat in a superposition of states (dead/alive) such that the act of external observation should collapse the indeterminacy. The problem is that things don't seem to actually behave like this. Why? Cordus explains that the paradox is based on unrealistic and unattainable premises. First, the cat cannot be placed in body coherence, and therefore cannot be in a superposition of states. Second, even if the cat (or something simpler like a superfluid) were placed in coherence, this is limited to spatial superposition: being in two places at once. Temporal superposition, being simultaneously in two different future states (alive and dead), is prohibited. Third, we accept, via the Principle of Wider Locality, that the act of observation changes a system. However it is not so much the act of observation that makes the difference, but the extent to which the hyff of the Observer's instrumentation system interact with those of the system under examination, i.e. the contextual intrusiveness. This concept is weakly represented in QM, and the original paradox merely proposes an act of observation. In contrast Cordus suggests that the presence of a passive Observer, one not directing fields, forces, photons, and particules at the system, is inconsequential. The radioactive material will emit a photon regardless of the presence or absence of a *passive* Observer, and the leaf will still fall in the forest whether or not it is observed. Of course more intrusive observation is different. Thus Cordus also has suggestions for the philosophical debate about the role of the Observer. Simply passively looking at the universe does not necessitate creation of another world.

*Fundamental effects*

Just think what else this idea might explain. Cordus proposes that the electrostatic, magnetic, and gravitational forces are carried simultaneously in the tension, bending, and torsion (respectively) of the handed hyff system. The synchronicity of the hyffons of neighbouring particules forms the strong interaction. Force is explained as a positional constraint on the re-energisation of a remote reactive end. Thus Cordus provides a conceptual unification of the forces, bar the weak interaction which we propose is a decay not a force effect. Cordus proposes that the vacuum consists of all the hyffons of all the particules in the accessible universe. This fabric is the medium in which the photon propagates. In the Cordus concept the fabric is relativistic and the speed of light is finite but not invariant. Could this be? If so, Time emerges as the frequency oscillations of matter, and its irreversible arrow occurs at the level where decoherence starts. Thus time is locally generated rather than absolute.

Cordus offers a physical explanation for antimatter as being particules with a mirrored hand of hyff system. This yields descriptions of the process of annihilation, the weak interaction and neutron decay. It also allows us to anticipate the discrete field structures of the neutrino, and explain the handedness of neutrino spin. Cordus also explains pair production, and photon emission/absorption. We might be wrong, but if we are correct then Cordus also provides an explanation for the asymmetry of baryogenesis, in terms of energetic antielectrons being remanufactured to protons with the waste stream being carried away by antineutrinos [10].

## Conclusions

We started with a thought-experiment questioning the 0-D point premise. From there we designed a viable hidden-variable solution, and demonstrated its relevance to many phenomena. So perhaps this cordus idea has value.

For a start, it delivers a workable non-local solution. Others will want to check the claim, but we suggest that it falsifies the Bell-type inequalities. The Cordus model provides a conceptually coherent model of internal variables, identifies their associated physical substructures, and proposes causal relationships for the behaviour of the particule.

Second, it has fitness to explain a variety of phenomena, and does so in a logically consistent way.[d] It accounts for many peculiarities where QM has not provided natural explanations. Conventional quantum theory would have us believe that its incongruent explanations are a consequence of the inability of human cognition to grasp the stochastic uncertainty at particle level. We suggest otherwise: that the weirdness is a defect and arises from an over-reliance on a flawed premise of particles being zero-dimensional points. While the Cordus model does not yet have detailed mathematics (there are exceptions), there is no obvious impediment to a mathematical formulism.[e]

Third, Cordus readily integrates the other physical theories. It accepts QM's mathematical formulism of the wavefunction, and reinterprets this as a stochastic representation of the average *geometric* position of a cordus particule over time, for objects that are not too small. Cordus also accepts electromagnetic wave theory and gravitation with their fields, these being reinterpreted as the massed behaviour of multiple particules.[f]

Fourth, the cordus idea provides deeper insights that are inaccessible to the existing conceptual framework built on 0-D points. There are radical new concepts for matter, force, time, and space. Cordus reconceptualises antimatter and parity, and anticipates the mechanisms for annihilation, pair production, and genesis. It also offers a conceptual unification of the electro-magnetic-gravitational and strong forces. The cordus idea systematically unravels many complex problems of physics.

The premise that particles are 0-D points without internal structure has been profoundly influential. It has served physics well. However we suggest that its time is up. We have provided a new construct for the internal design of particules, and thereby refute the premise of the 0-D particle. If we are correct, the 0-D point premise is an unnecessary conceptual hindrance, and a drastic reconceptualisation of fundamental physics awaits once the premise falls. Who would have thought that so much could hide in a bundle of nothingness?

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[a] *Superluminal entanglement* involves two geometrically separated particles, typically photons, affecting each other. If one photon is changed the other adjusts too (hence 'entanglement'), and does so faster than the speed of light ('superluminal'). It is thus non-local causality. *Local realism* is that the properties of an object pre-exist before the object is observed, and independent of observation. A similar, though not identical concept is *locality,* that the behaviour of an object is only affected by its immediate surroundings, not by distant objects or events elsewhere. Non-local theories are those that propose that a particle is somehow affected by remote events or fields that exist some distance away. While a non-local theory has the potential to solve a lot of fundamental problems (including entanglement), it also creates more of its own in that we don't obviously see non-local behaviour in our world. Also, it has historically been difficult to design non-local hidden-variable solutions, so they have mostly been discussed in a very abstract way. The pilot-wave theory of 1925 was the most recent solution of substance, and even then it was largely abstract.

[b] *Design method:* The design process can look very messy from the outside, as there is no step-by-step mathematical approach that will convert problems into solutions. Nonetheless it has a logic and purposefulness. In this particular case our design process involved the following: (1) creative lateral-thinking was used to create multiple reconceptualisation of the particle, all drastic; (2) inductive logic was applied to behaviours of the photon (we started with the double-slit device) to determine what internal structures and causality would logically be required in those new concepts, to support such behaviour; (3) we noted our premises as a series of lemmas; (4) deductive logic was applied to those premises to determine what they implied would have to be true in other areas, i.e. what the implications were for other phenomena; (5) we then explored those other phenomena and checked whether the cordus model could give coherent explanations; (6) recursive rework was performed on the concept or its lemmas where inconsistencies were found in the predictions or premises of the developing model; (7) multiple solution paths were pursued concurrently, each of these being only partly evident at the outset, there being many unworkable 'solutions'; (8) we then used the design logic of synthesis to combine the various principles into a holistic model; (9) we sought the fittest of these designs, the objective being to find a satisfactory rather than necessarily a perfect solution; (10) we repeated the process for more complex situations, e.g. matter phenomena, and thereby built up the capability of the model; (11) additional creativity was required throughout, not merely at the beginning, as new principles were needed for the extended concepts; (12) as more lemmas were added, so there were more opportunities for logical inconsistency, and hence further checking. At each stage of this process the concept with the greatest fitness was taken forward to the next level of checking. Thus the concept enlarged and became more detailed. The resulting Cordus model is conceptual and qualitative, and therefore its explanations are primarily descriptive. They are sometimes unorthodox, for which we do not apologise since that is not unexpected from design thinking. The Cordus model is an artefact of the design process, and we cannot be sure that a different process would not give a different model, and hence we refer to it as a conjecture.

[c] *Handedness*: The explicit handedness concept in Cordus is a useful concept, because it unlocks explanations to other deeper levels. Parity/handedness of the discrete HED field structures allows Cordus to: explain the differentiation between matter-antimatter; predict the internal structure of the neutrino and antineutrino; explain the selective spin direction of the neutrino and antineutrino; deliver a model for annihilation and pair production; offer a novel model for explaining asymmetrical baryogenesis. Those explanations are novel and radical, and have yet to be debated and their veracity determined. However the point we wish to

make is about the usefulness of questioning the things taken for granted. In this case we have questioned the 0-D point premise and replaced it with a new concept. This has provided a means to systematically unravel the complex problems of physics.

[d] *High fitness*: The cordus concept has been used to explain a variety of phenomena in physics. These include: Internal structure of the photon; Path dilemmas of the photon in the double-slit device and Mach-Zehnder interferometer; Wave-particle duality; Fringes; Near field; Beam divergence; Frequency of photon, electron and matter generally; Zeno effect; Uncertainty principle; Entanglement; Aharonov-Bohm effect; Pauli exclusion principle; Atomic bonding; Entropy; Superfluidity including quantum vortices and heat conduction; Superconductivity including Meissner effect; Josephson effect; Coherence including the limits thereof; Casimir effect; Tunnelling; Reflection; Refraction and Snell's law (new derivation); Brewster's angle (new derivation); Polarisation; Electrostatic field and granulation (quantisation) thereof; Magnetism; Gravitation and mass; Spacetime fabric; Relativistic nature of the vacuum; Finite speed of light in vacuum; Fine structure constant; Evanescent field; Colour of quarks; Mass excess; Parity violation; Antimatter; Annihilation process; Positronium decay including para and ortho forms; Pair production; Asymmetry of baryogenesis; Strong force (interaction); Unification of forces; Neutron decay; Weak interaction including decay processes; Structure of neutrinos including explanation of their handedness; Time. Explanations of these effects have been documented on the vixra physics archive, please see http://vixra.org/abs/1104.0015 as a starting point.

[e] *Mathematical formulism*: We have sketched the broad conceptual framework and provided a descriptive mechanics. Some may criticise it for lack of a mathematical model. We have deliberately not taken that approach since our intent was to prospect for faulty premises in foundational matters and conceptualise new solutions. It is not as if mathematical approaches have been very successful in tackling the fundamental questions of physics, with the exception of quantum chromodynamics and string theory. The design method is better at questioning existing premises, finding new concepts ex nihilo, providing grounded solutions, and expressing diverse abstract ideas in logically consistent ways. Nonetheless a mathematical formulism is expected to be feasible for cordus, and is a potential area of future development. The cordus model requires approximately eleven variables to define a particule, at this level. Compare this to zero for a zero-dimensional point plus a few more for its intrinsic spin, charge, etc. So a cordus mathematical model has more variables available. This is a good modelling position to be in, especially as all the cordus variables have an associated physical interpretation, hence an underlying logical consistency at the conceptual level. So a mathematical representation of the cordus concepts does not look impossible.

[f] *Additional integration*: There is a curious coincidence in the number of variables required for a cordus particule and the dimensions required by some string theories. Cordus requires about eleven variables, depending on how they are counted. String theory suggests that it should be possible to create a mathematical model for fundamental physics using about 10 or 11 dimensions (or variables), though it cannot give them physical interpretations. This is curious providing one is willing to equate internal variables with dimensions, which does not seem unreasonable. There is also a similarity in the structural models. String theory predicts that the photon is an open string, and cordus also predicts a photon particule with two free ends. Both have frequency ideas that are foreign to QM: cordus has alternating energisation of reactive ends, and string theory has oscillations. Is this a fluke? Or are they describing the same thing from different perspectives? Separately we have suggested that the probabilistic mathematics of quantum mechanics may be a high-level approximate representation of a deeper

determinism, more adequately represented by cordus-type models. It is too early to say, but there is the possibility that a wider integration might be possible between the quantitative point model of QM, the field models of electromagnetism and gravitation, the dimensional model of string theory, and the conceptual model of the cordus conjecture. Now that would be an exciting outcome from challenging the zero-dimensional point construct.