Limits of coherence: Where and why is the transition to discoherence?

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Abstract
This paper provides a conceptual solution to the questions of what causes discoherence and where the limits of coherence might be. Coherence is reinterpreted from the cordus perspective, as being a state when all the particules have synchronised frequencies and phases thereof, i.e. a form of complementary frequency state synchronisation (CoFS). Alternatively coherence can be perceived as a special state of assembly where the particules provide for mutual preservation of the de-energised locations of each other. Cordus anticipates three mechanisms for discoherence. First, a coherent material cannot accept internal shear velocity. Second, higher temperatures lead to decoherence because phonons (internal thermal vibrations) disturb the stability. Third, more complex assemblies of matter are harder to put into coherence, and the complicating factors are expected to be the number of components in the assembly, and the variety of species (simplicity and purity). Accordingly, the upper limit for coherence could be a simple crystal, or perhaps even a virus, with a limited number of species (different molecules or elements), at low temperature. However this is thought to be an optimistic prediction. This model predicts that coherence is already unachievable at the assembly level of the smallest metal grains, mineral crystals, and cell organelles, at ambient temperature. Thus warm macroscopic objects and living creatures cannot be put into coherence or superposition. However there is no problem with having coherent domains within a discoherent body, e.g. molecules that are internally coherent. Single particules, such as electrons, are self-coherent under any conditions.

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1 Introduction

Surprisingly, quantum mechanics (QM) does not apply to reality at our macroscopic level of existence, nor to the universe at large. To be sure, there are some contrary perspectives: e.g. the many-worlds theory, or observer-dilemmas (such as a literal interpretation of the Schrodinger's cat thought-experiment). Nonetheless the physical evidence is that QM does *not* apply macroscopically. The strangeness it that does apply so well to the particle level.

Quantum behaviour, specifically superposition of location, is only evident in particles and some microscopic objects cooled to close to absolute zero temperature [1, 2]. QM suggests should it should be attainable in larger

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and warmer objects [3], but this has proved difficult to achieve. Clearly there is a discontinuity in the physics between the small and large scales of nature. It is not clear where the boundary is between the quantum world of particles and the macroscopic world, and quantum mechanics itself cannot identify why there should be a boundary, nor where it would be.

Purpose of this paper

The purpose of this paper is to apply the cordus conjecture [4] to determine where in the scale of things the transition occurs between coherence and discoherence, and why the limits are where they are.

The point of comparison is the cordus conjecture, with its predicted internal geometry for particules. This paper builds on earlier work which explains why quantum mechanics does not scale up [5].

What is the cordus conjecture?

The cordus conjecture is a novel alternative theory of fundamental physics, constructed on a different concept for 'particles'. It is currently primarily a qualitative conceptual method [4].

The conjecture states that all 'particles', e.g. photons of light, electrons, and the protons in the nucleus of the atom, are not zero-dimensional points, but have a specific internal structure called a 'cordus'. The term 'particule' is used to differentiate this important conceptual difference from the QM construct. The cordus consists of 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 [6]. The reactive ends are energised (typically in turn) at a frequency [7]. The reactive ends emit one or more force lines called 'hyperfine fibrils' (hyff) into space, and when the reactive end is energised it sends a transient force pulse ('hyffon') outwards along the hyff curve [8]. This makes up the field, which is thus also discretised in 3D space. Various features of the hyff and hyffon carry the electrostatic field, magnetism, and gravitation simultaneously. Thus a unification of these forces is provided [9].

In this model the photon has a single radial hyff which it periodically extends and withdraws [6]. By comparison all massy particules have permanent hyff (including neutral particules like the neutron)[8], see Figure 1. Electric charge is carried at 1/3 charge per hyff, so stable particules like the electron are surmised to have three hyff, arranged orthogonally [10]. The hyff from multiple massy particules compete for the three hyff emission directions (HEDs), and may synchronise their emissions to access those spaces. Thus there is an element of mutual negotiation, based on shared 3D geometric timing constraints, and this explains the strong force [10].

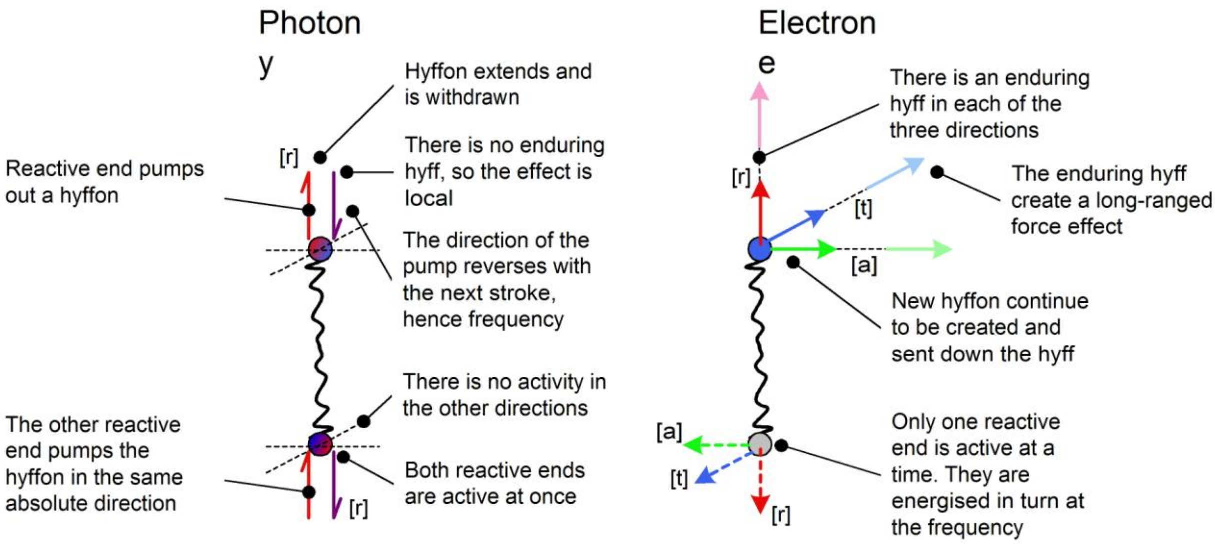

Figure 1: Models for the photon and electron, showing the different characteristics of their discrete field structures. The photon has a fibrillating pump that only shuttles energy outwards and then immediately afterwards brings it back inwards, whereas the electron consistently pushes hyffon (force fragments) outwards in a pulsating manner. Both cordi therefore have a frequency, but the difference is what they do with it. All other matter and antimatter behaves like the electron, though the hand of the hyff is inverted for antimatter, and the direction of pumping is reversed for positive charge.

In terms of its conceptual design, cordus has high fitness because it is able to explain many effects within one logically consistent framework [4]. However, cordus is a conjecture and the validity thereof is uncertain. Therefore derivatives of the idea, as here, should be considered speculative. They are also exploratory and subject to possible future revision.

2 Reconceptualising coherence

Reinterpreting coherence

We need to clarify what we mean by coherence, because doing so helps understand where it breaks down and why. As usual, the cordus concept that emerges is radically different to the orthodox interpretation, and these two should not be confused. Cordus refutes the QM concepts of *particle* and causal (temporal) *superposition,* though accepts positional variability [5]. The following explanation is summarised from [11] and [5].

From the QM perspective coherence is the ability for particles to interfere. This includes constructive and destructive interference of photons or waves (hence fringes), and dependencies ('correlation') between two different particles. The dependency may exist to a greater or lesser extent, i.e. involving more variables between the particles. There is also the matter of how strongly the dependency is preserved over time. The concept of coherence also includes the idea that only one wave or particle is involved: that its properties at one instant of time can be linked those at a different location or time ('self-coherence'). Examples of QM coherence at the large-scale include the laser, electrical superconductivity, and superfluidity. Nonetheless, even within QM there are differences of opinion about the interpretation of coherent states [12]. Quantum mechanics does not obviously apply to large bodies, living creatures, or the universe as a whole.

From the cordus perspective, superposition is simply that the cordus particule is actually physically oscillating between two positions: the locations of the reactive ends at the end of their span. The cordus particle (e.g. photon cordus) collapses to one of these ends when it is grounded [11].

Mechanisms for coherence

Coherence, from the cordus perspective, is when all the particules, which may be photons, electrons, protons, and possibly atoms & molecules, etc., have synchronised frequencies and phases thereof, i.e. a form of complementary frequency state synchronisation (CoFS) [11]. The bonds between any cordus particles are hyff and carry forces that synchronise the cordus frequency and phase of particules, providing the frequencies are compatible. We term this 'body coherence'. For photons in light beams, where the bonds are weak if they exist at all, the coherence may be mainly temporal and coincidental.

Coherence is a special state of assembly where the particules provide for mutual preservation of the twin locations of each other: when any one particule is energised at its one reactive end, the position of its other dormant reactive end is filled by the active end of another particule. Coherence is, according to cordus, best understood as an ordered complementary relationship (COFS) between two or more particules [11].

Thus in a coherent body, e.g. Bose-Einstein condensate or superfluid, the positions of all the reactive ends are locked together in a complementary sharing relationship. The positions of the reactive ends would otherwise change in response to external fields, perturbations from the fabric, and the impositions of impinging particules [13].

Particules in coherence with each other develop a negotiated state of sharing the 3D hyff emission directions (HEDs). (Much like planes shuttling between two nearby airports and sharing landing slots). External fields, which are also hyff whether from the fabric or nearby matter of the fields created by remote particules, can upset that negotiation. The coherent state has some protection from the close timing of the participating hyff (providing the material is pure): we see the same mechanism at work in the strong force. However with larger assemblies the HEDs are negotiated at longer ranges, and are therefore weaker, hence more vulnerable to disruption by external hyffons. Implicit in this cordus explanation is an idea that the external environment, even of the vacuum, consists of a fabric of hyffons [14].

Mechanisms for discoherence

All macroscopic objects in our world are discoherent as a whole. They cannot be coherent, and cordus gives three reasons why.

First, in the specific case of living creatures, there is a requirement for internal flows of matter, which is incompatible with the lock-step nature of a coherent material. To put this requirement another way, a coherent material cannot accept internal shear velocity (dynamic relative motion of the particules), though it can tolerate some shear strain (static relative deformation). This behaviour is also evident in superfluidity.

Second, hot bodies tend towards discoherence, because the resulting phonons (internal thermal vibrations) disturb the coherence. Quantum coherence is known to be a delicate state that is easily disturbed, as evident in the limited success with high-temperature super-states. Cordus is not a quantitative model and so cannot predict the temperatures involved.[2]

Third, more complex assemblies of matter are harder to put into coherence, and cordus suggests that the factors are simplicity and purity.

For a simple and pure assembly, consider two electrons sharing an orbital: a simple structure (only two particules) between pure components (homogeneous states of frequency, energy, etc.). (See Figure 2, level 3). This pair of electrons are coherent, hence the Pauli Exclusion principle. So the electron-pairs in a living creature are coherent even if the creature itself is not.

Atoms are more complex assemblies of particules with different masses, hence frequencies [7]. Cordus suggests that stability of these assemblies requires consonance of the frequencies of the individual components (hence the energy quanta of electron orbitals). Atoms manage this and are therefore internally coherent. (See Figure 2, level 4). Probably molecules too (level 5).

As with any coherent structure, the effect of an externally imposed change is communicated to neighbouring internal components at the next frequency cycle. For assemblies with high purity, this may be fast indeed, hence second sound in superfluids, and rapid electron transmission across biological molecules.[3] Hence also the successes in putting molecules into

[2] Cordus suggests that materials with stronger internal bonds should be capable of coherence at higher temperatures. This is because coherence is effectively the strong force writ large, i.e. a synchronised HED effect > it is already known that the strength of the strong force drops steeply with range > so the geometric nature of the assembly should determine the range of the required bonds, and thus the bonding strength within the assembly > some assemblies will have long-range hence weak bonds, and therefore be fragile to disruption by thermal phonons > the relationship between temperature and severity of phonon will need to be established.

[3] For a descriptive overview of quantum biology, and applications to odour reception, electron transfer in ATP, & photosynthesis, see Brooks, M., The weirdness inside us. New Scientist, 2011. 2832(1 October 2011): p. 34-37.

geometric superposition. Thus communication within atoms and molecules is rapid, being able to take advantage of the internal frequency network.

Many atoms of a pure material may be brought into coherence, though it apparently needs a low temperature (level 6) to reduce the phonons to a level that the bonds can withstand. Hence superfluids, and the success with the likes of pure iron objects showing geometric superposition at cryogenic temperatures.

However, as temperature rises, or the variety of components increases (purity decreases), or more particules are assembled, so coherence becomes difficult.

Thus, according to this model, coherence is already unachievable at the assembly level of the smallest metal grains, mineral crystals, and cell organelles. However, note that the atoms within those are always internally coherent.[4]

Macroscopic diamond crystals appear to have shown entanglement [15, 16], however the implications are debateable. That experiment sent a coherent photon into each of two diamonds at room temperature, using an interferometer, and observed that the resulting phonons were correlated for a short time (~7ps). Sending another photon pulse into the diamonds caused a coherent photon to be emitted. They interpreted that as entanglement of the phonons, i.e. that there arose 'a single phonon excitation distributed across the two crystals' (p1254). The cordus interpretation is the correlation between the phonons was simply a temporary artefact caused by a photon with two reactive ends.[5] From the cordus perspective, the reason the phonons were correlated at all was because (a) the beam splitter separated the reactive ends of the photon into two paths, and (b) the purity of the diamond material and its consistency between the two samples, so that the two phonons were initially sufficiently similar. Thus the subsequent measurement-photon, which followed soon after, was affected in the reverse way, and picked up the energy in the phonons. In this interpretation the phonons are merely a precarious short-term vibratory storage device for entanglement, rather than themselves being entangled. If the diamonds were replaced with variable and less pure materials, we would still expect to see phonons produced, but for their correlation to be lost sooner. It does not appear that they were able (in the absence of any mediating photon) to change

[4] Atoms *have to be* internally coherent, at least while they exist as atoms. This is because the interactions of the hyff emission directions create both the strong force holding the atom together, and the coherent behaviour.

[5] The competing explanation provided by the cordus conjecture: photons have two reactive ends separated by a fibril > the beam splitter of an interferometer sends the reactive ends down different legs > in this case for the input photon, one reactive end went into each diamond > each reactive end created a phonon in its diamond > those phonons naturally had inverse-symmetry, due to the communicative effect of the fibril joining the reactive ends > those phonons therefore initially showed correlation between each other, but this decays with time > a subsequent probe photon likewise sent one reactive end into each diamond > the reactive ends of the probe photon picked up the energy of the local phonon and assimilated it into the photon> the probe photon emerged with higher energy and was picked up at the detector.

one phonon and see the other likewise change. For this reason alone the claim is doubtful. This particular experiment is therefore evidence of geometric correlation of phonons, as induced by a photon that went down two paths after a beam splitter. It does not prove that the two diamonds were coherent, nor does it prove superposition of a single room-temperature diamond (not that those authors claimed the latter).

The cordus conjecture does not disagree with the QM idea that a photon or particule can be in two geometric places, but only accepts this one type of superposition, and argues that QM's concept of superposition inappropriately confounds two different effects: *positional* and *causal variability* [5].

As the variety of components increases, i.e. the purity decreases, and the assembly becomes more complex, then it becomes harder to find ways to arrange the cordus hyff, and thus coherence becomes harder to form/easier to lose, or simply inaccessible. Cordus suggests this boundary could be quite early in the overall scheme of assembly complexity, perhaps as early as the interaction of two dissimilar molecules (note *interaction* not *joining*). Once coherence is unavailable, the components within the assembly are unable to interact at their intrinsic frequency, but must instead act in response en-masse to the fields that each generates. This is a much slower form of interaction, and thus chemical reactions are slower.

Assembly level model

The three factors are therefore proposed as shear velocity, temperature phonons, and complexity of assembly. We summarise the assembly constraints in Figure 2.

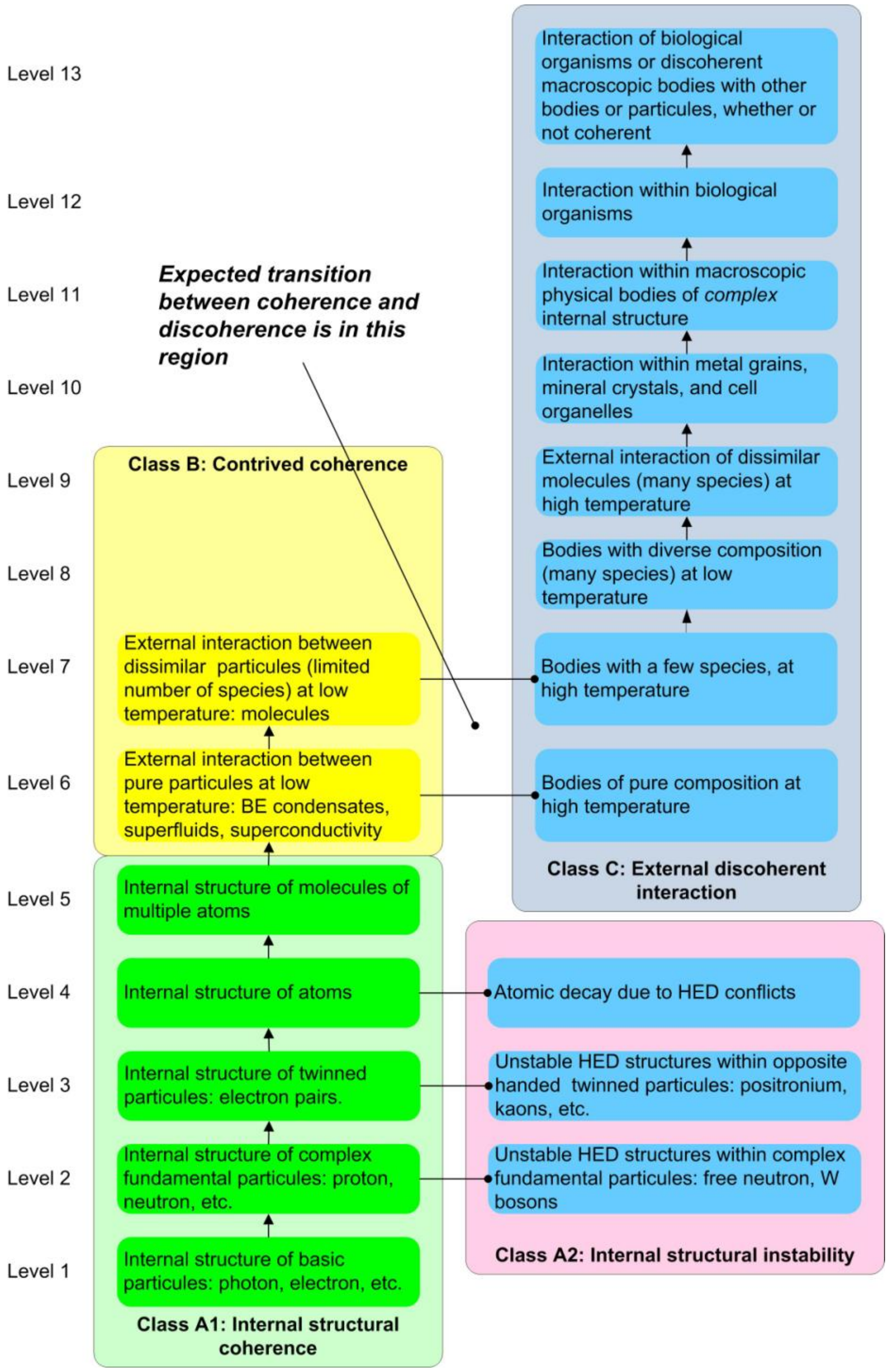

Figure 2: Assembly level diagram ranging from simple structures (level 1) through to complex (level 13). The different types of coherence are shown.

The diagram summarises the previous discussion, and introduces classes of coherence.

- Class A1 is for intrinsic internal coherence for individual particules ranging from the most fundamental through to molecules. This class should display superposition of location, though see [5] for fringe limitations.

- Class B is coherence that has been created by special situations, e.g. artificially, and is not stable at our ambient conditions. The low temperature superfluids are in this category.

- Coherence is a special type of stability, or bond, one based on the sharing of HEDs in the strong force. The discoherent state arises when either the coherent state becomes unstable, or cannot form in the first place. Therefore we include Class A2 with some examples of internal instability such as the W bosons and positronium. Cordus predicts that these materials will not support lasting coherence.

- Finally, we provide Class C for the complex matter assemblies. These are naturally discoherent for the reasons given above.

Where is the upper assembly boundary for coherence?

According to this cordus model, the upper limit for coherence could be as high as Level 7: External interaction of *dissimilar* particules (limited number of species) at low temperature. For example a simple crystal or perhaps even a virus, at low temperature. This is the optimistic prediction. To our knowledge it has not yet been achieved: only *pure* materials have shown the behaviour so far. Therefore a pessimistic prediction is that the limit has already been reached, at Level 6: External interaction of *pure* particules at low temperature.

We expect that discoherence is unavoidable at Level 9, where a body consists of numerous species of matter, at ambient temperature. We also predict that a many-species body (level 8) will be discoherent even at the lowest temperatures.

So we can, using cordus, estimate that the transition occurs at the end of level 7 (limited number of dissimilar species, cold), though we acknowledge there is some uncertainty.

Coherence in biological systems

There is no doubt in this model about the discoherence of macroscopic objects and living creatures: Cordus predicts it will be impossible to achieve coherence for macroscopic objects at ambient conditions (level 11), or put them into superposition. This does not preclude coherence effects, e.g. rapid electron transport, from occurring in the molecules within biological systems. However it does exclude superposition (of either kind), double-slit behaviour, and fringes.

3 Discussion

From the cordus perspective, coherence is interpreted as all particules in an assembly having synchronised frequencies and phases thereof. In the cordus explanation this is a form of complementary frequency state synchronisation (CoFS) [11]. This also involves the sharing of hyff emission directions (HEDs).

Thus there is a common mechanism for the strong nuclear force, Pauli Exclusion principle, bonding within molecules, and coherence. Consequently coherence can be perceived as a type of bonding and stability arrangement. Alternatively it is a special state of assembly where the particules provide for mutual preservation of the de-energised locations of each other. Thus positions of all the reactive ends are locked together in a complementary sharing relationship.

Cordus anticipates three mechanisms for discoherence. First, a coherent material cannot accept internal shear velocity. Second, higher temperatures lead to decoherence because phonons (internal thermal vibrations) disturb the stability. Third, more complex assemblies of matter are harder to put into coherence, and the complicating factors are the number of components in the assembly, and the variety of species (simplicity and purity). We represented this as an 'Assembly level model'.

Comparison to the QM explanations

The conventional QM explanation is that decoherence arises because the object has many particles, hence too many degrees of freedom (DoF). This DoF idea finds support in this cordus model.

QM also proposes that the atoms are strongly coupled to the external environment. However QM is unclear about how that coupling mechanism works, or why it should be so much stronger than the atomic bonds, or the bonds for coherence. In the cordus interpretation the way the coupling with the external environment operates is through disturbance of the negotiated HEDs.

Both cordus and QM recognise that temperature and the resulting atomic vibrations (phonons) can destroy coherence. However QM is does not explain how that happens (how is a 0-D point affected by phonons?). In contrast, cordus readily explains it as phonons causing displacement of the reactive ends, and thus interrupting the existing HED arrangements with other particules.

Upper limit for coherence

According to this cordus model, the upper limit for coherence could be a simple crystal, or perhaps even a virus, with a limited number of species (different molecules or elements), at low temperature. However this is thought to be an optimistic prediction.

Thus, according to this model, coherence will be unachievable at the assembly level of the smallest metal grains, mineral crystals, and cell organelles, at ambient temperature. Macroscopic objects and living creatures are therefore well beyond being put into coherence or superposition. However there is no problem with having coherent domains within a discoherent body, e.g. molecules that are internally coherent. Single particules, such as electrons, are self-coherent under any conditions.

The interaction of biological organisms or discoherent macroscopic bodies with other bodies or particules, whether or not coherent, is always discoherent. This implies that Observers of a quantum experiment are not themselves in a quantum state of superposition.

The theory of QM has created an expectation that coherence is the norm and therefore should be found in macroscopic bodies. Cordus suggests that we should instead view discoherence as the normal state, and coherence as a special state of extended application of the strong force into bonding. There has also been much philosophical speculation about the role of measurement, including human observation, on the future of behaviour of particles and coherent bodies. Cordus likewise refutes those ideas, and instead suggests that in those rare cases where coherence of macroscopic objects is attainable, this does not mean that the object has two futures, only that it can have two locations.

Conclusions

This paper has applied the cordus conjecture to determine where in the scale of things the transition occurs between coherence and discoherence, and why the limits are where they are. The reasons for discoherence are proposed to be internal shear velocity of the body, temperature phonons, and complexity of assembly (particularly purity of composition). The upper limit for coherence is expected to be at currently achieved levels of material complexity, or slightly beyond. However cordus rules out coherence for warm macroscopic objects and living creatures.

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