Cordus matter: Part 3.2 Matter particuloids

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Abstract

Some of the most enigmatic effects in the physics of electrons are its wave-particle duality and the Aharonov-Bohm and Casimir effects. Even relatively core concepts of atomic physics, like spin and the Pauli exclusion principle, lack satisfactory descriptive explanations. This paper shows that application of the cordus principle can explain these effects in a coherent manner.

Keywords: electron; wave-particle duality; spin; atomic bonding; de Broglie frequency; matter wave

1 Introduction

While matter forms the tangible substance of our world, our understanding of it at the atomic level is far from complete. Conventional physics is based on the assumption that the constituent particles of matter are just that: one dimensional particles.

Thus Quantum mechanics (QM) asserts that the properties of a particle, e.g. spin, are simply intrinsic, and that the fundamental reality for particles is probabilistic and described by a wavefunction. This is adequate for explaining many classes of effects. For example, the electron is known to pass through the double-slit device and QM has an adequate mathematical explanation for this. However in the same situation electrons are also observed behaving as waves, and this wave-particle duality is poorly explained by QM.

The present paper extends the Cordus concept to the electron and then to matter generally. It is shown that this yields an explanation for several electron effects, including wave-particle duality, Aharonov-Bohm effect, spin, a descriptive explanation of the Pauli exclusion principle, atomic bonding, and the Casimir effect. This paper is the second of five parts on the Cordus concept applied to matter.

2 Cordus model of the Electron

Previous Cordus papers have explained how the photon could be a cordus rather than a single 1D point. Electrons also make fringes, and therefore it is logical to extend the cordus concept to the electron. This permits the

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apparent wave-particle duality of the electron to be explained. It also handily explains several other features of the electron, including the Pauli exclusion principle for orbitals. The following lemma extends cordus concepts to the electron.

Lemma M.2 Electron

The conjecture is that the electron itself consists of a type of cordus.

M.2.1 The electron is another type of cordus (e-cordus) and has an e-fibril and e-hyff (electrical field).

M.2.2 The fibril of an electron exerts a restoring force on the span.

M.2.3 The electron's fibril is of similar functionality to that of the photon.

M.2.4 The electron oscillates and appears at the end of its fibril (energised Electron End) at a frequency (tentatively assumed to be the de Broglie frequency).

M.2.2 The e-cordus gives the electron two RE statistical *mode* locations where it can appear, and when the electron is bound to an atom, these appear as an orbital or energy shell around the nucleus.

M.2.2.1 In this context a *mode* is an available location for a reactive end. While the cordus only has two REs, it may have more than two modes available to it, due to the space around it.

M.2.2.2 If a cordus has multiple modes available to it, then the next one it uses will be determined by the hyff of other cordi in the environment. Thus cordi influence the location of each other.

M.2.5 The energy shells are in quantum increments because they need to include whole frequency-cycles (wavelengths).

M.2.5.1 At a deeper level, not that we need the explanation for present purposes, this is determined by the need for multiple standard gauges of assembly in the atom, see ‘Cordus in extremis’, competing with the need to maintain a CoFS state throughout the atom.

M.2.6 Higher energy electrons have higher frequency.

M.2.7 Higher energy electrons have shorter cordus span.

M.2.8 The RE modes of an electron within an atom are shaped (not necessarily symmetrically) by the hyff of other electrons in the atom.

M.2.9 continued below

This lemma may be used to provide a Cordus explanation of several effects. Later it will be shown that other sub-atomic particles may also be represented as cordi.

2.1 Wave-particle duality of the electron

The Cordus explanation is as for the photon (ref Cordus Conjecture): the free unbound electron oscillates its appearance between its two reactive ends. Thus it is able to pass through two slits that are suitably spaced apart. The fibril passes cleanly through the medulla between the slits, without interacting. Fringes arise similarly: the reactive ends have electromagnetic hyff, and thus engage with the edges of the slits in passing, generating forces, thereby incrementally deflecting the electron, and creating fringes.

2.2 Aharonov-Bohm effect

In the Aharonov-Bohm (AB) effect an enclosed magnet, one from which magnetic field cannot escape, changes the motion of an electron even though the particle passes through a magnetic-free region. The experiment involves a coherent source[3] of electrons: one beam passes through the centre of a toroidal magnet and the other bypasses it; the electrons thereafter interfere to produce fringes at a biprism (wire with a positive charge);[4] the fringes differ depending on whether or not the magnetic flux is confined to the magnet (as opposed to leaking into the hole). The conventional explanation involves use of vector electromagnetic potentials (in place of electromagnetic fields).

The significance of this effect is that the electron is affected by a condition (magnetic field) that is some distance away from it, and to which it does not have access. Thus the principle of locality seems to be compromised, as in the case of entanglement. The results are usually interpreted as evidence that QM's mathematical representations of electromagnetic potentials are not simply mathematical, but are real effects.

The Cordus explanation is: one reactive-end of the electron cordus goes through the toroidal magnet, and the other goes past it; the reactive-end itself does not get into the toroid but its hyff do; the hyff penetrate the (thin) outer layer of the solenoid, and therefore are able to probe that space despite the electromagnetic barriers preventing the electron as a whole from entering; the hyff interact with the magnetic field and this causes a displacement force on the reactive-end; the wire of the biprism provides the edge-effect for the formation of fringes.[5]

Thus the AB effect, from the Cordus perspective, is another application of the Principle of Wider Locality.

[3] The quantum mechanics concept of a 'coherent' source of light or electrons is not accepted by Cordus, at least not as QM describes it. Instead Cordus explains this type of light source as reactive ends that have been split to go down two paths.
[4] The fact that fringes in this case are associated with electromagnetic effects at the edges of objects, is consistent with the explanation for photon fringes ('Cordus conjecture'), which are also edge effects.
[5] The present working model is focussed on the reactive-end perspective, and it is possible that an alternative way of looking at it is that the fibril passes through and is disturbed by the magnetised region.

2.3 Electron configuration, Orbitals, Spin

Electrons that are bound to atoms have specific configurations of shell, sub-shell, orbital, and spin. The standard perspective is that the energy levels for the electron are in quanta, i.e. discrete steps. These are explained as arising from the need for the levels to be spaced at whole numbers of the particle's wavelength, and Cordus is similar in this regard (M.2.5).

Synchrotron radiation

One of the difficulties with the classical model of the atom is that if an electron orbits round the nucleus, then it should emit a photon (synchrotron radiation) and collapse into the nucleus. Quantum mechanics partly solves this by providing orbitals in which there is only a probability of the electron appearing. However this is an incomplete solution as it does not explain how the electron gets from one location to another, and why it should not emit a photon while doing so.

The Cordus interpretation is that the electron is not continuously in existence but appears and disappears at each of the ends of its fibril. When it is not in existence (dormant) then it does not have to emit synchrotron radiation. Furthermore, the position of those reactive-ends changes depending on the rest of the local environment of the atom and neighbouring atoms, because of the influence of the hyff of other electrons. The positions of the cordus correspond to the orbitals, i.e. the RE modes. Existing models of the orbitals suggest they are generally spherical or contain multiples of two modes (most likely locations). The two-ended nature of the cordus readily lends itself to this type of outcome. There is no actual 'orbit' in the continuous sense, and hence no radiation of a photon. This does not mean that the electron is stationary: only that it steps around its orbital, and moves invisibly between steps. When it has multiple modes accessible to it, then the choice is influenced by the hyff of surrounding electrons. (See also superconductivity below).

However, when the electron is free of the atom and flowing en masse in a circular path then there is a small net rotation and translation of the *whole* e-cordus at each frequency cycle, and synchrotron radiation occurs there.

Electron orbital shape

Both QM and Cordus suggest that electrons are not orbiting balls. QM predicts that the shape of electron orbitals is not a circular orbit, but rather a shaped region of probable location. For example, the s orbital is spherical and has zero angular momentum, whereas the p orbital has polar modes. The higher orbitals are not necessarily symmetric. However all the orbitals have a bipolar shape, even if distorted. This is consistent with the cordus concept of an electron with two RE modes (M.2.2), where the modes are shaped (not necessarily symmetrically) by the other electrons in the atom (M.2.8) and molecule (M.3.5).

Note that higher energy electrons in an atom, will according to cordus, have shorter spans (and higher frequencies). They will therefore need to either be closer in to the nucleus, or arrayed around the outside. This is counterintuitive in that conventional models suggest higher energy electrons are further away from the nucleus.

Spin angular momentum

Particles, including the photon, are known to carry spin angular momentum. In classical mechanics angular momentum is rotation of a body around an axis. From the QM perspective, spin refers to a property of the particle, and it is quantised. QM believes it to be an intrinsic property, i.e. there is no internal structure nor any actual spinning about an axis. The spin for fermions (e.g. electrons, quarks) is in ½ units of spin. For bosons (e.g. photon) it is integer units. It is also known that the spin of a particle is functionally identical to angular momentum, as shown in the empirical Einstein–de Haas effect (electric current in a coil causes a magnet to rotate), and the complementary Barnett effect (an object becomes magnetised when spun). Trying to reconcile those is not easy, so spin is conventionally left as a disjoint concept: Classical mechanics can't explain quantum spin, and Quantum mechanics can't explain angular momentum of a particle.

From the Cordus perspective there is significance in the magnitude of spin: it comes in discrete quanta of ±1/2 multiples of the reduced Planck's constant $\hbar = h/(2\pi)$, which is termed the spin quantum number. Why ½? Why not 1/3 or some other fraction? Cordus suggests that the ½ spin arises from a cordus with two rather than any other number of reactive ends. Each time the cordus re-energises, the next reactive end is 180^o offset from the previous one, not 120^o as would be for three REs. The implication is that the re-energisation of the cordus is functionally equivalent to a single reactive end that rotates in 180^o increments.

Cordus suggests that the conventional concept of spin confounds two similar but different effects: the frequency oscillation whereby the two reactive ends take turns at being energised, vs. the hyff (force field) that those REs emit. Thus the following clarifying lemmas.

Lemma M.2 continued

M.2.9 Spin is compound concept and more usefully partitioned into different types, based on the underlying mechanics.

M.2.9.1 Cordus-spin: Half-spin fermions (matter particles: electron & leptons, quarks, & composite particles) are cordus structures with two reactive ends.

M.2.9.1.1 The re-energisation of the cordus is functionally equivalent to a single reactive end that rotates in 180^o increments. This creates angular momentum.

M.2.9.1.2 The whole photon cordus can rotate in roll about its flight *a* axis. Thus a photon may have either left- or right-handed circular-polarisation: neither more nor less states than two.

M.2.9.2 Reactive-end spin: Half-spin fermions can share locations of their REs providing they are in complementary frequency states. Specifically, two electrons can be in the same location, including an orbital, providing they have opposite spin.

M.2.9.3 Hyff-spin: Integer-spin (±1) bosons have two variants.

M.2.9.3.1 The elementary type are what Cordus calls hyff, and contribute to the Cordus theory of fields. These are what QM calls virtual particles. Multiple hyff force fields can share the same space.

M.2.9.3.2 Atoms with full orbitals, e.g. helium-4, have integer spin overall. This only means that they have zero net angular momentum.

M.2.9.4 The photon (but not the virtual photon, which is covered by M.2.9.3)[6] is an exception in that it has elements of multiple spin behaviours. This is an artefact of the way compound-spin is defined.

Thus plain 'spin' is an overloaded concept that should not be used without clarification. It primarily refers to the number of reactive ends in the cordus, and secondly to the ability of cordi and hyff to share space. Thus spin refers to the frequency model of the particuloid.

Pauli exclusion principle

The Pauli exclusion principle is that electrons (and protons, neutrons, and fermions in general) must have opposite spin if they are to occupy the same space. In contrast the photon (and bosons in general) have integer spin and can co-locate.

From the Cordus perspective, this is covered by M.2.9.2: the exclusion principle represents the fact that each orbital in the atom can be filled with only two electrons (no more), and these electrons must have opposite spin. The cordus explanation is straightforward: the electron cordus has two ends, only one of which is fully energised at any one time, and two such cordi can co-habit, providing they are in *different* phases. They achieve this by making complementary frequency state synchronisations (CoFS), mediated through their hyff.[7] Cordus further suggests that these pairs of electrons are entangled, i.e. they are actively influencing each other. The hyff are never completely off, except momentarily, so the two electrons can affect each other's location and frequency states.

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[6] The photon and the 'virtual photon' are very different structures according to Cordus: the photon is a cordus, whereas the virtual photon is just the hyff component of the cordus. Cordus questions the validity of the term 'virtual photon' since it implies a particle.

[7] This is a stable configuration for the electron because it means that when it is dormant or out of its second mode then another electron is looking after the mode. The two electrons guard each other's modes, and this strengthens their ability to resist disruption by hyff from other electrons within the atom and externally, hence the stability, and lower chemical reactivity.

2.4 Atomic bonding

The cordus idea extends to explain how bonds operate between atoms. Each orbital around an atom has two modes (locations) and requires two full-time-equivalent electrons to fill. However a electron does not have to be dedicated to the atom: it may be part-time, with only one cordus-end in the atom under consideration, and the other in a neighbouring atom. Doing this creates a bond between the atoms.

As every electron has two cordus reactive-ends, it therefore has two possible RE mode locations. Cordus suggests that the ability of the electron cordus to have one end associated with one atom and the other end with a different atom is the underlying mechanism for all bonding between atoms (M.3.1, see below). Multiple electrons can therefore bind (M.3.2) a series of atoms together into larger molecules, providing the atoms are sufficiently close that a geometrically suitable orbital can be offered to the valence electron (M.3.3).

Cordus does not specify whether or not, *within one atom*, all the electron cordus-states are synchronised to just two complementary states, *for all orbitals*: i.e. whether the atom as a whole is in a CoFS state. Presumably it is, at least to some extent, since the relationships between the inner electrons and the nucleus would seem likely to impose constraints on the outer electrons (M.2.8). Regardless, the bonds *between atoms* will presumably propagate synchronisation across at least the orbitals involved (M.3.4), and this means into other atoms in the molecule. Thus to some extent the molecule as a whole will be in an entangled state. Thus cordus predicts rapid transmission of information within a molecule.

These concepts are summarised in the following lemma.

Lemma M.3 Electron-mediated covalent bonds

M.3.1 Electron covalent bonds are created when one end of the electron cordus is in a different atom.

M.3.1.1 A covalent bond is effectively a shaped orbital, but between two atoms rather than only inside one.

M.3.2 The electron cordus is elastic and can exert force that keeps the ends from separating, i.e. generates a force that bonds the atoms together. (The photon may not have this capability).

M.3.3 Suitable geometric arrangement of the atoms is necessary for bonding to occur: the valence electron needs to have access to an orbital that is sufficiently within the constraints imposed by its span, and therefore by its energy. Electron energy, span, available orbitals, and geometric spacing are therefore bonding factors.

M.3.4 Electrons that are shared between atoms are in CoFS states with *both* atoms.

M.3.5 Covalent bonds within the molecule distort the shapes of the electron orbitals.

Electron bonds have some strength. This is presumed due to the restoring force of the fibril. When the span is increased, i.e. two reactive-ends of the electron are separated, then the fibril (or the hyff) exert a force that brings them closer together (M.2.2). However the restoring force does not close the span completely, but only keeps it within some range of default-span. Free electrons have a default span inversely proportional to their frequency (M.2.7).[8]

Ionic bonds are electrostatic attraction effects, caused by the metal having less affinity for its electron than the non-metal. Van Der Waals force may be caused by the hyff of electrons protruding beyond their orbitals, especially when existing covalent bonds within the molecule distort the electron orbitals (M.3.5) and thus cause polarisation effects.

Casimir effect

The Casimir effect is a closing force between two conductive plates that are close together. The effect also occurs in a vacuum, i.e. when there is no intervening matter. The conventional explanation is that electromagnetic quantum fluctuations occur around the plates, but those in a narrow gap are weaker than outside, so a force arises pushing the plates together, i.e. a type of pressure effect.

The Cordus explanation is that the plates are so close that some electrons have a reactive end in each plate, and thus their fibrils exert a closing force, just as in any other electron bonding situation. The Casimir effect requires that the plates be conductive, and Cordus interprets this as necessary for the provision of mobile electrons. According to Cordus it is the way the electron hyff are free-ranging that causes the effect, which in turn depends on the material properties (which can be manipulated). The cordus explanation is similar for the Jospehson effect, where electrons can cross a thin insulating barrier.

3 Application to matter generally

de Broglie equations

The de Broglie equations describe the wavelength of matter: (a) Wavelength $\lambda = h/p$, i.e. is inversely proportional to momentum p, and (b) frequency $f = E/h$ with kinetic energy E, and Planck's constant h.

This wavelength is for moving particles. Such a particle appears to behave as a wave in its ability to diffract into fringes at gaps or double-slits. For example, electrons form fringes in the double-slit experiment. From a classical perspective this is unexpected behaviour for a 'particle', and the usual explanations are that the particle behaved as a wave with the de Broglie frequency. Quantum superposition of states and probability theory is another explanation. The de Broglie equations imply that a particle at rest does not have a wavelength or frequency.

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8 However the span in a bonded situation is different: any span-deviance is accommodated by loaned energy from the other electron, via a small phase difference in the complementary synchronisation. See also the Level of Assembly concept in 'Cordus in extremis'.

Curiously, the direction of the frequency is ambiguous. The same problem was encountered with frequency in the case of light waves and photons (ref. Cordus Conjecture). The quantum perspective is a wave-packet interpretation: that the particle is a travelling packet of waves. This conveniently also provides an explanation of a sort for Heisenberg's uncertainty principle. However the wave packet idea introduces issues of its own, namely the need for not one but many frequencies to make up the packet. What does the de Broglie frequency correspond to in a wave packet? What does 'frequency' correspond to in a particle, and to what do all the wavefuntion frequencies physically correspond? To those existential questions quantum mechanics has no answer other than the mantra that there is nothing deeper, not any internal variables, but that the mathematics is the reality.

Cordus frequency for a particuloid

The Cordus perspective is that all fermion matter 'particles' are cordi (M.2.9.1), and oscillate their appearance at the ends of their span. This readily accommodates the idea that matter has a frequency, and Cordus goes further to state that matter had a frequency *even at rest*. The Cordus and de Broglie concepts of frequency are very different, and should not be confused. [9] The cordus frequency concept is further developed in the following lemma.

Lemma M.4 Matter

This lemma extends cordus concepts to matter generally.

M.4.1 All particles including the electron, proton, neutron, and quarks, may be represented as cordi. Thus they have a fibril, reactive ends, and hyff of some type.

M.4.2 The cordi oscillate with a frequency. This means that matter does not exist as single-point particles that are continuously in existence. Instead matter oscillates its appearance at either end of the cordus span. The cordus frequency is tentatively assumed to be the de Broglie frequency.

M.4.3 The direction of frequency oscillation represents a polarisation variable. It is assumed to generally be transverse to the direction of particle velocity, but not exclusively so.

M.4.3 The cordus frequency exists even when the particle is not moving.

M.4.4 The larger the mass the higher the frequency.

M.4.5 The higher the frequency the shorter the span.

M.4.6 Bonds, e.g. those between protons and neutrons, and also those between atoms, carry forces that can synchronise the phase of particles with compatible frequencies, hence coherence.[10]

[9] The cordus frequency is not the same as the de Broglie frequency. Cordus frequency applies to all particuloids, whether or not they are moving, whereas de Broglie only applies to moving particles. Cordus does not have a specific frequency for moving particles, but instead includes a motion effect on frequency in 'Cordus in extremis'.

[10] When the internal coherency fails, the atom decays.

M.4.7 Increased kinetic energy of the particle causes increased frequency.[11]

M.4.8 Temperature does not apply to a single particle, but to aggregates of matter, being the vibrational energy stored in the bonds between atoms (phonons), in turn caused by electrons in stretched orbital modes.

M.4.9 Assemblies of particles, e.g. molecules and bodies, generally do not have an observable overall body cordus frequency, unless they are brought into a state of coherence.

Matter waves

The 'matter wave' phenomenon is explained as a cordus particuloid with velocity. The oscillation is transverse to the velocity. Heavier cordus particles have higher frequency and shorter span. Hence a microscope using electrons has greater resolution than one using photons. The moving cordus particle has hyff and these engage with the edges of gaps and cause quantum angular deflection of that reactive end, hence fringes. See also 'Wave particle duality of the electron' above, and 'Large-body matter-waves' below.

From the Cordus perspective the phenomenon is not really a 'matter wave' but only looks like a 'wave' because the fringes happen to also follow wave mathematics.

What is the diameter of a particle?

Physics has several interpretations for what a particle consists of. Mathematically it is treated as a 1D point source, without internal structure. At other times it is considered to be a sphere. And at yet other times it is considered to be made up of further 1D points. For example, the proton has three quarks (UUD) held together by gluons.

The general premise is that a particle is a stable aggregate of one or more semi-permanently existing sub-particles, hence that it is meaningful to ask questions like 'what is the diameter of the particle, e.g. proton?' From a cordus perspective this is an invalid question: it is not meaningful to talk about the diameter of say a proton, as if it had a hard surface.

From the Cordus perspective the elementary particle, e.g. photon or electron, is not a sphere in the first place, but rather a two dimensional rod (or multiple rods), with fuzzy ends too. Nor does it permanently exist in one location, but instead oscillates its existence at its reactive ends. Also, cordus suggests that the zone of influence of the particle extends well beyond its geometric modes. The proton is likely to have hyff that create a zone of influence: this may be somewhat diffuse, perhaps shaped, and the outer zone may be considerably larger (though weaker) than commonly perceived.

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[11] This lemma is included for consistency with de Broglie's equation. However it is not immediately needed, and the mechanism is unclear. An *in extremis* speculation is that the motion of a particuloid may cause the span to realign normal to the direction of motion, and that the effect is dependent on mass (hence momentum).

Existing methods of attempting to measure the 'diameter' of the proton involving measuring its interaction with electrons, either in bonding situations or impact-scattering. From a Cordus perspective these experiments are measuring the average interaction geometry of the electron and proton, not a physical diameter. It is natural to call this the 'diameter' of the proton, but that really is only an interpretation based on the a priori assumption that a particle *should be* a sphere of charge. Cordus further suggests that the measurement is dependent on the probing particle. This is consistent with the observation that the diameter of the proton is measured to be smaller when the muon is used as the probing particle.[12] Any cordus particuloid, the proton in this case, adjusts its span depending on the other particuloid it needs to interact (bond) with. Thus the effective interaction geometry depends on the participants in the interaction, and presumably their energies too. There is no solid physical diameter for a particuloid. A proton will therefore have many 'diameters' depending on what interaction is being measured.

So it does not make sense to think of a particle as a sedate, stable, solid, in-one-place, well-defined sphere (of mass or charge), as if it were a planet. It is more like a moving cracking whip. Cordus suggests that composite 'particles', e.g. the nucleus as a whole and the individual proton, have complex interactions within, as the multiple internal cordi all seek their place to exist. Furthermore, as the photon cordus relates in some way to that of the electron, so it seems possible that other sub-atomic cordi-particuloids could also be comprised of yet smaller cordi interacting in various ways.

Thus it is not meaningful, from the Cordus perspective, to perceive the atom as hard little balls orbiting around a nucleus made of compacted other balls, as shown in the popular symbol for the atom.

4 Conclusions

Some of the most enigmatic effects in physics have been wave-particle duality generally, and in the case of the electron specifically, the Aharonov-Bohm effect, and the Casimir effect. Even relatively core concepts of atomic physics, like spin and the Pauli exclusion principle, have not previous had satisfactory descriptive explanations. The conceptual contribution of Cordus is that it provides explanations for these effects. Moreover, these explanations are consistent with its explanations in other areas, as the companion papers show, so the emergent model has a high degree of coherence.

This paper has provided a re-conceptualisation of the electron. It is implied that the same principles apply to matter generally. The better understanding of the electron that emerges from this paper is useful in developing a model of other electron functions, particularly its interaction

[12] The proton would be expected to be slightly heavier in this case, see 'Cordus in extremis'.

with the photon, and the energy cycles within matter. These are the topic of part 3 in this series. The cordus model for the electron is also important for the special states of matter discussed in part 4.