Cordus in extremis: Part 4.1 Electromagnetism

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Abstract

The Cordus conjecture is extended to create a conceptual model for electromagnetic fields. The resulting model shows how a cordus particuloid generates small transient units of force at the sub-atomic level, thereby creating the apparently smooth and continuous electric field that we more commonly perceive. Cordus also reconceptualises how magnetism is generated at the sub-atomic level, and likewise explains how the granularity arises. It is shown that the electric field cannot be shielded, only neutralised. Cordus electromagnetism is applied to explain the electric field surrounding a wire carrying current, the locus of moving test charges in a magnetic field, and the mechanism for how force arises in permanent magnets. The contribution made by this paper is a description of electromagnetism that goes to the next deeper level: it explains the underlying mechanisms for how the forces arise. Also, it provides a mechanism for fields to be granular and directional at the small scale, but smooth and continuous at larger scale.

Keywords: cordus; electric; field; electrostatic; magnetism; electromagnetism; quantum field; hyff; particle

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1 Introduction

The Cordus conjecture provides a radically different interpretation of the photon, and by extension, sub-atomic particles in general. Companion papers have applied the Cordus concept to show that it provides a conceptual resolution of wave-particle duality for the photon (ref: 'Cordus Conjecture'), explains optical effects (ref: 'Cordus optics'), and explains 'particle' effects (ref: 'Cordus matter'). This paper extends the concepts to fields in general, and in doing so provides a reconceptualisation of electromagnetism, gravitation, vacuum, mass, and quarks. The Cordus conjecture offers some suggestions for thinking about these subjects, though the treatment should be considered *in extremis,* i.e. a thoughtful-experiment rather than a necessary core concept. This paper is the fourth in the Cordus series, and itself consists of four parts. It is recommended that these parts be read in the numbered series, since the concepts are cumulative.

Background: Cordus

The Cordus concept is that the photon and all massy 'particles' are not one-dimensional (1D) points as conventionally assumed, but consist of

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two reactive ends (RE) connected together with a fibril. The reactive ends emit hyper-fine fibrils (hyff), which are threads of transient force, see Figure 1. The periodic renewal of the reactive ends corresponds to the frequency of the photon or 'particle'. In the case of the photon the hyff are extended and withdrawn during each complete frequency cycle. The Cordus concept has also been shown to be applicable to other so-called particles, e.g. the electron (see 'Cordus matter'). From the Cordus perspective there are no such things as 1D point particles, only small-span cordi that only *appear* to be particles. Thus matter is made up of cordus particuloids. For matter cordi like the electron, the electrostatic hyff (e-hyff) are not withdrawn at each frequency cycle, but continue to propagate outwards. Each frequency cycle sends a renewal-pulse down the hyff, so the force is transient and quantised. This force makes up the electric field.

A companion paper (Cordus conjecture), describes the background to this idea, applies it to path dilemmas in the double-slit device and Mach-Zehnder interferometer, and uses it to explain fringes. It is shown that the Cordus conjecture is conceptually able to resolve wave-particle duality for the photon. Another paper (Cordus optics) shows that the idea is applicable to conventional optical effects, such as refraction. That paper also further develops the concept of frequency and the dynamic internal states of the photon. A third paper (Cordus matter) applies those ideas to matter generally and the electron specifically. It explains matter waves and the wave-particle duality thereof, entanglement, locality (a revised principle is proposed), electron orbitals, entropy, coherence, superfluidity, and superconductivity. It also shows why quantum effects do not scale up to the macroscopic world. We recommend that 'Cordus conjecture' and 'Cordus matter' be read first, as the present paper extends on concepts described there.

One of the positive features of the Cordus idea is that it is coherent across many physical effects, as shown in the companion papers. The implications are that both electromagnetic Wave theory (WT) and Quantum mechanics (QM) are only external manifestations and measurements (respectively) of a deeper mechanics. Neither of them, singularly or jointly, is the reality.

Purpose

The Cordus concept as a whole is conjectural, although the previous papers have grounded the concepts by comparing them against well-known physical phenomena. The present bracket of papers is less cautious. The purpose here is to audaciously push the concept to see if it has novel suggestions about deeper mechanisms, particularly the propagation of light and fields in general.

Method

The approach taken is a continuation of that described in 'Cordus conjecture', and not detailed here. The purpose is to synthesising a working-model that is sufficient to explain as much of the observed reality as possible. The outcome is qualitative rather than mathematical, and is termed a *conceptual solution*. Along the way the underlying assumptions are notes as a series of *lemmas.* These we do not attempt to prove: they are simply to make the premises explicit so that they can be evaluated later. In the other papers the causality is relatively linear, but here the concepts were found to depend on each other, and the process of generating the conceptual solution was more iterative. The way the model is presented is therefore for convenience of explanation rather than necessarily descriptive of the method. Unavoidably, concepts are sometimes mentioned at the start but only defined later. The lemmas make up the central strand through the papers. L lemmas are in 'Cordus conjecture', O in 'Cordus Optics', M in 'Cordus matter', and E in 'Cordus in extremis'.

The results follow, starting in part 1 with some basic preliminary constructs for the electric field, then magnetism. Part 2 introduces a concept for what the vacuum consists of, and why the speed of light is finite. Gravitation, mass, and time are explored in Part 3 and new models developed for each. Part 4 introduces a conceptual model for quarks and the internal structure of the proton and neutron.

2 Field forces

The fundamental forces are electromagnetism (EM), strong and weak nuclear forces, and gravity. Electromagnetism and gravitation are the only forces with infinite range.

2.1 Quantum mechanics interpretation of fields

The QM explanation is that the forces arise between matter by the exchange of gauge bosons. These bosons are the force-carriers, and the photon is held to be the gauge boson for the electromagnetic force. The other forces are carried by W & Z bosons (weak) and gluons (strong). The force effects are described using bosons as virtual particles, which can only be detected as forces not individual particles. Thus electromagnetism is proposed to be carried by virtual photons, the strong interaction between quarks by the gluon, and the weak interaction (e.g. quark flavour-changing between left-handed fermions) by W and Z bosons. Thus the standard explanation is that electromagnetic forces arise between matter when they exchange virtual photons. These forces can cancel each other if the bodies have both protons and electrons in equal numbers.

Gravity is the odd one out. All the others can be explained by QM. Gravitons *may* be the force-carrier for gravity, though this is more controversial and the particle has not been observed and detection is generally expected to be difficult though perhaps feasible. The other approach to gravity is general relativity, where gravity arises from the warping of space time, i.e. the effect is a geometric one. However this does not integrate very well with QM. The Cordus interpretation of fields and bosons is very different, and is progressively developed in several sections following.

2.2 Cordus electrostatics

The starting premise is that all fields are hyff, of one sort or another. The following lemma sets out the assumptions more explicitly.

E.1 Hyffon lemma

E.1.1 All field forces are carried by hyff.

E.1.1.1 The hyff are persistent structures and each particuloid of matter has a finite number of them.

E.1.2 Some hyff continue to propagate outwards (gravity, electromagnetism) and hence have long range, whereas others are withdrawn (photon hyff).

E.1.3 A hyff is a persistent structure even when not energised. Hyff are in pairs: one part at each reactive end (RE) of the cordus.

E.1.4 A hyff line is directional but may be bent, e.g. by movement of the basal generator.

E.1.5 The hyff carries a transient quantum of force ('hyffon') directed back down the hyff towards its origin. Each re-energisation of the reactive end sends another renewal-pulse of force down the hyff. We term that pulse a hyffon since it is reminiscent of phonons and plasmons in their distortion of the medium. The hyffon corresponds approximately to 'gauge bosons'.

E.1.6 Each hyffon renewal-pulse of hyff force has the ability to interact with other 'particles' of matter that it meets. The force is transient and is relinquished as the pulse decays, at least for the electrostatic hyff (e-hyff).

E.1.7 The hyff propagate forward and the force is not consumed but reapplied to the next most distal particuloid of matter.

E.1.8 Hyff penetrate everything. No field can be shielded.

Therefore hyff are directional force lines that extend out into space from their basal particuloid, and where the force appears in pulses that travel outwards along the line (hyffons), see Figure 1. The hyff themselves are not being continuously created, but they are being energised by pulses (hyffons) that travel down the line.

2.3 Electric field

Applying the lemma to the electric field, the Cordus interpretation is that the charged cordus particuloid at the *base* emits an electric hyff (e-hyff) at the moment of its creation, and that hyff continues to propagate outwards with each pulse of renewal. This implies that charged particles created at the birth of the universe will tend to have their hyff moored at the edge of the expanding universe. Each electron is not necessarily bound to a single proton somewhere else in the universe, so electric charges may be monopoles, at least at the level that we perceive.

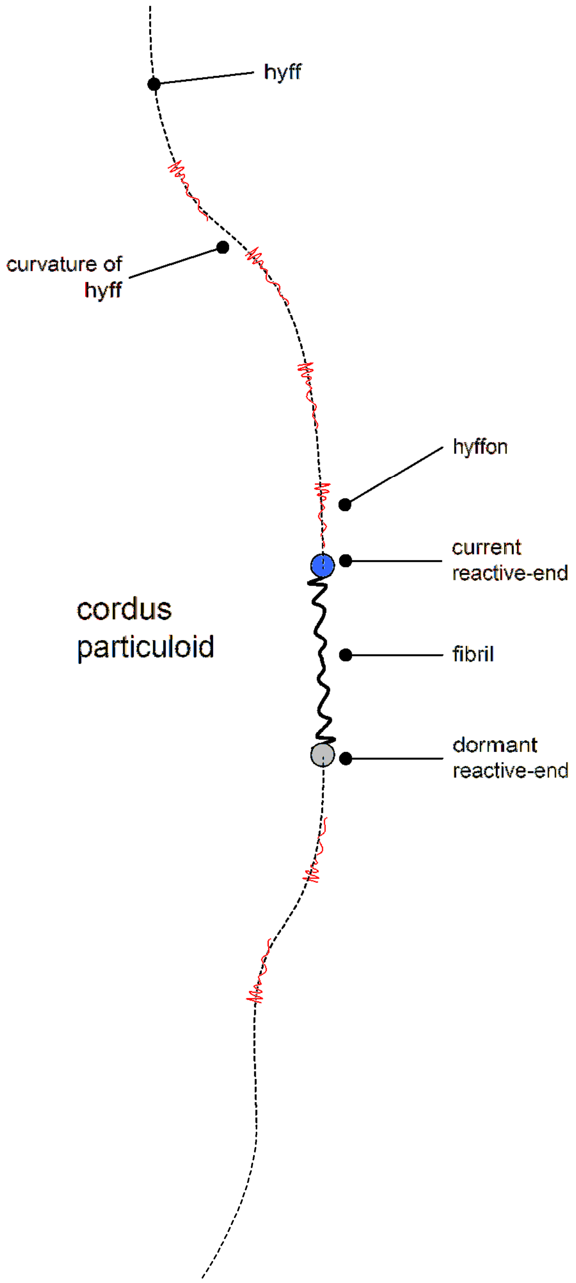

Figure 1: Cordus structure showing hyff and their periodic re-energisation via hyffons emitted consecutively from the reactive ends. A fibril joins the two reactive ends and perpetuates the frequency and the reciprocating energisation of the reactive ends. Only one pair of hyff is shown. Later works suggests that the proton and probably also the electron have three, in orthogonal directions. Photons are thought to have only one pair of hyff, but they are not persistent as shown here.

Thus fields consist of a rapid sequence of discrete impulses of transient force, radiating out from a cordus at the centre. However we do not see this granularity at our level of perception. Instead we perceive fields to be smooth, continuous, and uniform in all directions. This is because of the en-masse effect of many particuloids being involved, so the hyff lines are numerous and in different directions, and the frequency is too high to detect the individual pulses.

For a test charge in an electric field, the overall effect is a steady rain of hyffons that are individually small transient units of force. The overall effect is a smooth force. If the remote body has depth, then the incoming hyffons apply force to the fore-most parts of the body, and then pass through and apply force to the deeper layers.

Hyff lines for permanent charges like the electron are persistent, though renewed periodically by hyffons. By comparison, the photon is odd, in that it emits an electric field and then promptly withdraws it: the next pulse is in the opposite direction.

Electrostatic Shielding

It is commonly known that an electric field can be shielded, whereas gravitation cannot. For example, a Faraday cage is a container made of conductive mesh, and is conventionally understood to block external electrostatic fields from entering: no electric field is experienced inside.

However Cordus suggests that something different is happening, and proposes a different principle: Hyff penetrate everything, and no field can be shielded. In a Faraday cage the electric field only *appears* to be shielded. That in turn is because electrons in the cage material, which has to be conductive, have sufficient mobility to move rapidly to the other side of the cage in response to the external field. There they set up own field countering response fields, i.e. an induced voltage across the cage. The external hyff (and field) still exist inside the cage, but the net force on a test charge is zero because it is balanced by the induced voltage field across the cage. The fineness of the cage-mesh determines the roughness of that field, so better results are had from finer or continuous materials.

Electrons in the cage need to make this balancing at the frequency of the externally applied field. For static electric fields this is straightforward, as the electrons need to move into position only once, hence the requirement that the cage be conductive. When the frequency of electric field is too high then the electrons cannot respond fast enough: in which case the balancing fails and shielding is lost.

Note that it is the hyff that cannot be shielded. The electron or photon or particuloid itself *can* be denied passage: shielded or reflected. Thus when considering shielding or reflecting, it is important to note that the effects are different for hyff and reactive-ends. Also, the effect is different for photons because the do not have persistent hyff but rather extend and then withdraw them. Photon hyff do not pass through everything, or at least do not go far. Therefore the photon can be shielded against: it can be absorbed. So light can have a shadow but not the electric field.

Applying this to reflection of radio-frequency *photons*, as the frequency increases so the span of the photons decreases (see 'Cordus conjecture'), and the available current loops in the shield need to be correspondingly smaller if the photon is to have a chance of meeting them: hence the mesh-size of the reflector needs to be finer. As the frequency rises still further, the required loops are of the order of atomic spacing, i.e. the shield must be of a continuous material. For even greater frequencies the electrons cannot counter the hyff so the photon passes straight through.

The hyff always go through everything, but the cordus particuloid itself, represented by its REs, can be blocked, reflected, or collapsed. Once the RE has been displaced, then the next hyffon is emitted from the new location. So the inside of the Farady cage *appears* to be free of electric fields, whereas Cordus suggests the fields are *not shielded* but merely balanced. The implication is that hyff penetrate everything, and *no field* may be shielded, though some may be balanced (E.1.8). This is may seem a trivial distinction, but is important in what follows regarding gravitation.

Virtual particles

The conventional perspective is that the virtual photon is the gauge boson (force carrier) for the electromagnetic force. As shown above, the Cordus interpretation is different: the electrostatic hyff carry the force and there is no invisible additional particle per se. From the Cordus perspective conventional references to 'virtual particles' of any kind can generally be re-interpreted as a hyff effect (E.1.1). The hyff have a renewal frequency, and travel as a hyffon pulse in the *fabric* of space (see part 4.2) A hyffon only looks like 'virtual particle' because it involves transient disturbance of the medium, and is not an identifiable real particle. Cordus suggests that the term 'virtual particle' is misleading and confounds two very different effects: the REs of the cordus particuloid, and the quantum hyff force fields.

If this is true, then it means that seeking to find gravitons as the force-carrier for gravity, can be re-interpreted as a search for hyffons. These can be expected to be small disturbances in the fabric hyff (see Part 2), not particles as such.

Cordus suggests that hyff are permanent for matter. Assuming nominal units of charge q- and q+, which are not necessarily those of the electron and proton, then the q-hyff are outward propagating, whereas the q+hyff are inward (a nominal sign convention). As the universe expands, so the hyff get stretched out. Note that the hyff are *not* straight lines, but are distorted into curves by the velocity and acceleration of their basal particuloid.

2.4 Cordus magnetism

There are different perspectives on magnetism. The classical electrostatic description is that static charged particles create only an electrostatic field, whereas moving charged particles create a magnetic field too. The two components are primarily related by change: when an electric field changes or is moved it generates a magnetic field (and a changing magnetic field creates an electric field). Thus a charged particle placed in the fields will move accordingly under the Lorentz force, F = q(E + VxB) where F is force, q is electric charge, E is electric field, V is velocity, B is magnetic field, and x is the cross product using the right-hand-rule.[2]

From the perspective of special relativity, electric- and magnetic-fields are part of the deeper phenomenon of electromagnetism. The two are interchangeable depending on the frame of reference: what looks like a magnetic field from one frame could be electrostatic in another. The quantum perspective is that electromagnetism occurs by the transfer of (virtual) photons. From the wave theory perspective, light is an electromagnetic wave, with the electric and magnetic fields perpendicular to each other.

Cordus provides a different explanation. Magnetic fields, from the Cordus perspective, just represent the motion of the charge (basal generator) that is emitting the e-hyff. This is based on the following assumptions.

E.2 Magnetism Lemma

E.2.1 Movement (velocity) of a charged reactive end causes magnetic field. The mechanism is presumed to be bending of the hyff at the basal emitter.

E.2.2 Curvature of e-hyff is magnetism. The hyff are bent when the base charge moves, and this curvature is propagated out on the hyff by the hyffon pulses.

E.2.3 The direction of magnetic field is perpendicular to the plane in which the curvature occurs.

E.2.4 The electric field is the fundamental effect, and the magnetic field is a derivative.

E.2.5 A remote particuloid responds to the hyffon pulses and the curvature embedded therein.

E.2.7 The mechanism for magnetic interaction is a yaw moment on the remote moving particuloid.

From the Cordus perspective, a static charge only generates an electrostatic force, without magnetism, because the hyff are straight outwards. However a moving charge *causes* bending of the e-hyff, and this is what we perceive as magnetism, see Figure 2. The sharper the radius of curvature the greater the magnetic field. Thus electrostatic forces are a position effect, while magnetism is a velocity effect. However the same basic structure, the hyff, is responsible for both.

Fields are granular directional effects

Cordus suggests that both the electrostatic and magnetic effects are directional for a single moving charge (the 'base charge'), i.e. the force is orientated in a particular direction. This is a consequence of the assumption that a single charge has a limited number of hyff, and the effects travel out on the hyff. It is easiest to understand as a single radial hyff, but that is a simplification for convenience of explanation.

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[2] Right-hand-rule: V along thumb, B on index, and then the force is in the direction of the middle finger, for a positive charge

The emission direction of the hyff at the reactive end (proximal) can be changed, but if the charge has existed for a long time, which will generally be the case, then the far (distal) end of the hyff will be in another point in space, and at a different orientation.

For a stationary base charge, the hyff lines are straight outwards. Thus any small stationary test charge placed at some remote location along the hyff will feel only the electrostatic force from the base charge. A granular electrostatic force occurs when a hyffon reaches a remote test charge. The force, which is momentary, is directed tangent to the hyff *at that remote location.* The electrostatic effect is directional, so Cordus predicts that a test charge will only feel the force if it happens to be sufficiently close to the hyff line, and otherwise not. So the electric field is both granular and directional, at small scales. However in most practical settings the number of charges involved is large, they all point in different directions, and the cordus frequency is high. These cause a smoothing effect, and consequently the resulting field is continuous and uniform. So the overall effect is not directional. The same smoothing applies to the magnetic field.

Generation of magnetism from a single moving charge

When the basal charge moves, then the hyff line is bent or displaced at the proximal origin, see Figure 2. The resulting piece of curvature moves outward with the hyffon pulses, reforming the mature line ('combing') as it moves out to the distal end. Thus a remote test charge placed somewhere on the hyff receives updates about where the basal charge is now located, which means that the *electrostatic* force is more accurately aimed back at the base. The test charge will also feel the *magnetic* force, depending on its own velocity. The hyff process of propagating this information occurs at light speed.

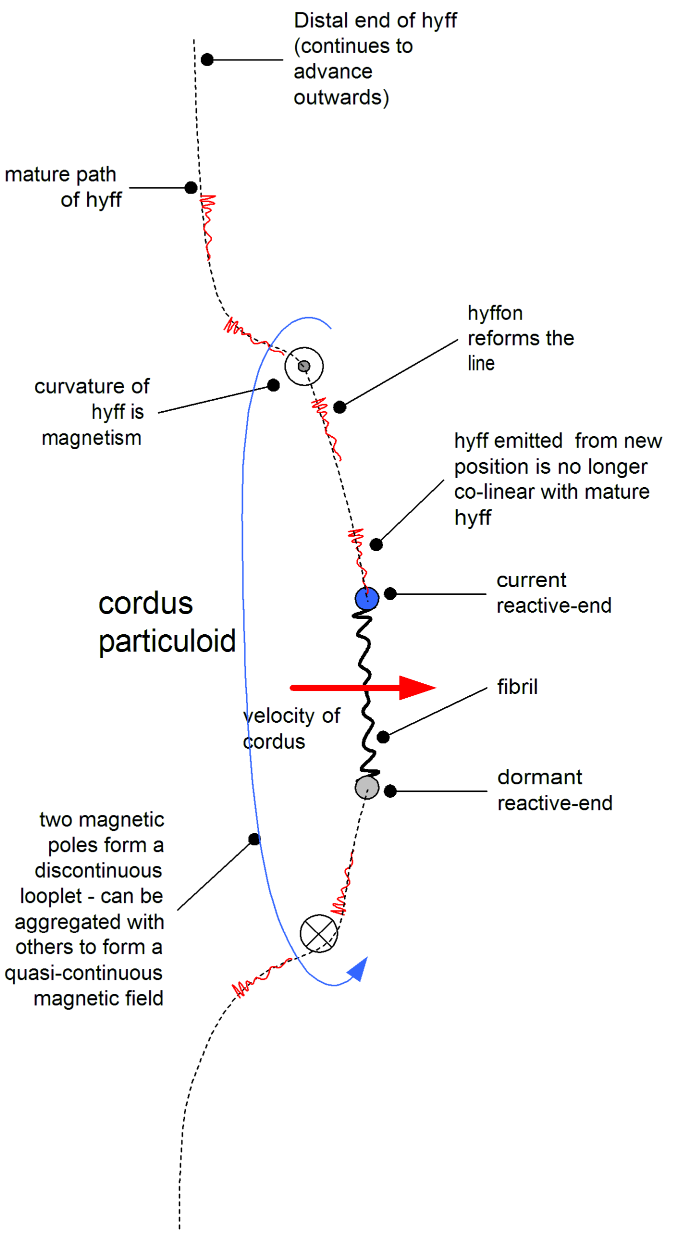

Figure 2: Magnetism is curvature of the hyff in the Cordus model. This curvature creates a fragment of magnetic force, which moves outwards with the hyffon.

In this particular working model,[3] the magnetism effect is an impulse of force that can act on a remote moving charge that gets in its way. The directional hand[4] of magnetism VxB ensures that the magnetic impulse is in the opposite direction at the other reactive end. However it is not sensible to speak of a magnetic *field* in this simple case. The overall field is

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[3] In a different model the magnetism corresponds to positive and negative curvature of the hyff, in which case there is a looplet around *each* hyff. This is not the currently preferred model, but at this relatively high level of conceptual abstraction there is often not a lot to differentiate the models, so we have to be open to the possibility that the model might need changing.

[4] Why is the effect right-handed? What are the deeper variables that cause this hand? E.6.11 suggests it is the way the quarks assemble into matter, i.e. the way the hyff are orientated in the assembly of matter particuloids.

generated by aggregation of the many small discrete fragments of magnetism. Each moving charge creates part of a magnetic looplet, not necessarily continuous, and the effect of multiple charges moving together is to aggregate those into a what we perceive as a continuous field.

Any moving mass generates curvature of the hyff, and these generate the magnetic field, except that neutral-charge mass has no observable magnetic field because it emits positive and negative hyff. However Cordus suggests that at a sufficient small scale neutral mass should show magnetism, because the positive and negative basal generators are separated slightly.

The curved path of the hyffon is a discrete impulse of both electrostatism and magnetism. These forces travel together, and as they move outward they are diluted across the surface of an enlarging sphere, and thus the field effects becomes weaker. This advancing front is an area effect ($A = 4\pi r^2$), not a volume effect, which is consistent with the observation that the electrostatic, magnetic and gravity forces all reduce with radius squared (r^2) rather than any other power.

The faster the base charge moves, the greater the distortion of the hyff, and the greater the magnetic impulse (so the force is not a fixed quantum). Having more charges q moving in the same direction does not increase the curvature but simply means that there are more hyffons reaching the remote test charge, i.e. the effect is simply additive.

When the base charge *stops* moving, then the curvature of the hyff is quickly (again at light speed) swept straight by the hyffons. The end-result is a straight hyff line. So magnetism subsides and only the electrostatic effect remains. Magnetism is thus only evident when the base charge has velocity.

Thus one mechanism, the hyff, simultaneously transmits the electric and magnetic forces. Thus Cordus accounts for all the terms in the Lorentz force, $F = q(E + VxB)$. The strengths of the two forces are not equal, being determined by the electric constant electric constant (or vacuum permittivity) and the magnetic constant (or vacuum permeability). Cordus explains this as different efficacy of the two sub-mechanisms of the hyff.

Generation of magnetism in a wire

An electric current in a wire generates a magnetic field that wraps around the wire (right-hand thumb rule). Cordus explains this as follows. When electrons flow en-masse in a wire, they each emit a few hyff, and these aggregate to create a smooth magnetic field. The component of any hyff emitted axially forward or backward will neutralise with those of other electrons, so the net result is hyff emitted radially. Thus the looplets (see Figure 2) join to form the observed cylindrical field structure.

Reaction of a remote moving charge to magnetic impulse

How does a curved hyffon create the magnetic force on the remote test charge?

If the remote test charge is stationary, then any curvature of the incoming hyff (i.e. external magnetic field) only re-orients the *direction* of the electrostatic force.

However, if the test charge is also moving, and encounters a magnetic field, then the magnetic force arises. The basic principle is that the force tries to realign the moving test charge to the same direction of motion as the basal charge. For example, if the magnetic field is large and uniform, then the transecting moving test charge is forced into a circular path: which is the same as the large basal current required to make that magnetic field. The principle applies also when the two moving charges are the same, except that they mutually influence each other to try to become co-linear. Thus magnetism is one moving charge attempting to force another to conform to the same direction of motion: it is a type of synchronisation effect.

2.5 Magnetic interaction

The classical interpretation is that a test charge moving in a magnetic field experiences a sideways Lorentz force that is perpendicular to its direction of travel and the *external* magnetic field (i.e. excludes the magnetic field of the test charge itself): F = qV**x**B. However the *mechanism* for how this forces arises is obscure.

The following is a speculative model for the mechanism underlying cordus magnetism. This is an explanation for Lemma E.2.7 which states 'The mechanism for magnetic interaction is a yaw moment on the remote moving particuloid.'

Progressive model

The magnetism effect starts as an angular deflection of the emergent hyffon at the basal charge (E.2.1), and this propagates outwards on the hyff as a pulse of curvature (E.2.2), eventually reaching the remote moving test charge (E.2.5). But how does the hyffon interact with the remote charge in E.2.7?

The following working model is suggested, though it is speculative. The basic principle is that the pulse of magnetism interferes with the re-energisation of the reactive ends of the remote test charge, thereby encouraging that remote charge into a different position than its momentum would usually have provided, and this is what is experienced as the magnetic force.

E.2.7 Magnetic interaction lemma

The mechanism for magnetic interaction is a yaw moment on the remote moving particuloid:

E.2.7.1 Velocity of any massy particuloid delays the re-energisation of its reactive ends and thus the emergence of its hyffons.
E.2.7.2 Delay corresponds to energisation of the reactive end in a geometrically retarded position on its locus, i.e. the fibril is momentarily not perpendicular to the direction of motion. The hyffon is emitted slightly rearwards, which corresponds to a transient kink in the hyff.
E.2.7.3 All charged particuloids are assumed to have mass. The momentum of the moving particuloid subsequently carries the reactive end forward to where it should be in the locus. Thus the retardation does not accumulate.
E.2.7.4 At the remote moving charge the process is complementary.
E.2.7.5 Particuloids always line up their span to be perpendicular to their direction of motion, and will adjust their spin to achieve this. (However the roll angle is variable).

Cordus explanation

A somewhat fuller explanation follows. Within the basal moving charge, the a1 reactive end is delayed slightly by the velocity (E.2.7.1), and the need to emit the hyffon onto the *fabric* of space (see part 4.2). The a1 reactive end therefore energises in a geometrically retarded position on its locus (E.2.7.2). Thus the fibril is rotated in yaw, momentarily, and the hyff is temporarily bent as it is emitted. The momentum of the moving particuloid resets the system by subsequently carrying the reactive end forward to where it should be in the locus.

When the hyffon curvature pulse reaches the remote moving test charge, it likewise interferes with the geometric location for the emergent reactive end b1 of the moving test charge. Whether it delays or advances that reactive ends depends on the sign of the magnetic field, i.e. the relative direction of the velocity of the test charge. The pulse may prevent the b1 reactive end advancing forward as far as it usually might during a frequency cycle, or it might push it forward. Recall that momentum determines the nominal location on the locus where the reactive end is expected to re-energise. Remember also that a reactive end will preferentially re-energise in a location prepared for it by the external environment. So the basal charge remotely interferes with the *location* of re-energisation of other particuloids. This sets up a yaw moment across the fibril, thereby adjusting the direction in which the remote charge is moving.

The curvature pulse is not consumed but passes on outward to the other RE b2. We assume that the effect is additive rather than being negated, since the hand is reversed when it reaches that other reactive end.

Particular cases

If the test charge is not moving, then the curvature pulse only interferes with the spin of the test charge: it rotates it on the spot.

If the test charge is moving in the same general direction as the base charge, then the pulse yaws the cordus of the test charge towards the direction of the basal charge. Of course the moving test charge is not simply a passive participant, but also radiates its own hyff with electric and magnetic effects. If the basal charge is of similar size, it will be affected in turn by the magnetism of the test charge, and the two charges will progressively synchronise their positions towards each other, i.e. the loci converge, or the magnetic force is attractive.

The magnetism effect depends not simply on the speed of the charges, but also their relative directions. This is economically explained in cordus by adding lemma E.2.7.5: that particuloids always line up their span to be perpendicular to their direction of motion. (However the roll angle is variable). Thus magnetism only works in remote particuloids that already have some degree of alignment with the velocity of the basal charge.

If the remote test charge is moving in some other deviant direction, then the hyff it emits are orientated differently to that of the base charge. The field of the base charge partly forces the remote test charge to comply. This means that it will be forced to partly synchronise its hyff emission with the base charge, (a weak form of CoFS in action) and in turn this means that its reactive ends will have to energise in a different position and orientation than their own momentum had originally intended. Thus the general result of magnetism on two similarly sized moving charges, is to redirect their trajectories towards each other.

The common case shown in physics texts is of a moving charge being forced into a circular trajectory in the presence of a uniform magnetic field. In this case the magnetic field dominates the interaction, and the moving test charge tends to move into a circular or helical trajectory. However the uniform field is not a particularly useful way of representing magnetism because it obscures the important fact that creation of that uniform field requires charges to be moving in a circular path too. Uniform magnetic fields are a very special case and thus an artificial way to approach magnetism, and it is the dance of two moving particuloids where the more interesting mechanics becomes visible.

The implication of the E.2.7.5 lemma is profound, because it means that any motion of a massy object results in all the internal particuloids adjusting their spin. This sounds radical, and it may or not be valid. Nonetheless there are several situations where we do see something similar albeit with magnetism, namely permanent magnets, and magnetic resonance imaging. In both these cases the spins of all the electrons in the whole body are aligned, and in the latter case it is the human body which is affected, to no obvious detriment. The cordus lemma suggests that the effect not only applies to magnetism, but also to motion.

To sum up the magnetism mechanism, the incoming hyffon interferes with the intended re-energisation of the reactive ends, and changes the preferred location. Thus there is a transient displacement effect that we interpret as the magnetic force. Magnetism thus interferes with momentum processes. [5] Note that the force and displacement perspectives for magnetism are equivalent. Thus the classical interpretation of the Lorentz force F = qV**x**B and the cordus displacement mechanism are different aspects of magnetism considered at different scales.

Permanent magnets

A permanent ferro-magnet has a magnetic field, but no apparent electric field. The usual explanation is that that the electron and nucleon spins are aligned across a domain (region of atoms).

The Cordus interpretation extends this by saying that that the alignment of the cordus (spin) of electrons and nucleons result in the hyff pointing in the same direction. More accurately, that the hyff are orderly aligned along the axis of the magnetic poles, but randomly orientated in the transverse directions and there neutralised layetally. The electrostatic force on an external test charge is balanced, because of the equal contribution of positive and negative charges. So the magnet does not appear to be charged or to emit an electric field. Nonetheless it emits hyff.

From the Cordus perspective, the magnetic domains are formed in the first instance because electron hyff extend to neighbouring atoms and encourage alignment: a complementary frequency state synchronisation (CoFS). This is an important concept throughout the cordus mechanics, and 'Cordus matter' describes the concept more fully. Within the magnetic material the electrons themselves move, either through their unfilled orbitals, or current flow within the sub-lattices of the material, and this generates curvature of the hyff and thus magnetic fields. These curved pieces of hyff propagate outwards to reach a remote magnetic material, e.g. a piece of iron. At this point they induce the remote electrons and atoms to align with the hyff and move with the direction of curvature, if the atomic structure permits (paramagnetism). While the electrostatic forces are balanced, the magnetic components are not, and the residual component of force is attractive (or repulsive if the atomic response is diamagnetic).

How does the force itself arise? The piece of iron is attracted to the magnet, and the hand must exert force to prevent it closing the gap. How does this work? The explanation for this working model, is that the force is a perception: the real effect is displacement at the sub-atomic cordus level. The hyffons of the magnetic field put pressure on the electron cordus in the iron test piece, and this encourages the reactive ends of the electron to re-energise in a slightly closer position than they would otherwise. These are lower-energy positions in the environment external to the cordus, so the reactive ends naturally prefer to re-energise in these locations. The REs can be prevented from doing so, but this requires a force. For an electron deep inside the iron test piece, that force is carried by the neighbouring electrons, and the stability of those bonds. The force

[5] It should therefore not come as a surprise that cordus predicts a coherent system behaviour across electricity, magnetism, momentum, mass, and gravitation, as the following papers show.

is therefore carried from electron to electron through the bulk of the iron until it reaches the outside surfaces, where the pressure of the hand provides (again through electron interactions between iron and tissue) the force to resist the movement of the iron piece.

So, to answer the question, when holding two magnets apart, the force is required to prevent the sub-atomic cordi (e.g. electrons) from inching closer to the other body. If that force is not there, then the two bodies accelerate towards each other.

Acceleration of a body in a field

If the hand is not there, or the biomechanics not strong enough, then the REs of the electrons in the iron creep closer to the magnet, by a small increment each frequency cycle. Once they start moving, the test piece of iron obtains a body speed, and this with its mass creates momentum. In turn the momentum predisposes the reactive end to re-energise ahead on its locus, i.e. the velocity is maintained. The steady rain of magnetic hyffons keep pulling the REs in the test piece even further ahead, and this creates acceleration. The mechanism is similar for a body accelerating in any field: electrostatic, magnetic, or gravitational.

Thus from the cordus perspective all three fundamental forces are caused, at the sub-atomic level, by displacement effects of the reactive ends. The *fabric* provides the medium that interlinks all these effects, see part 4.2. Thus what we perceive as force is more fundamentally a constrained-displacement effect. This is also why the speed of light is a common limiting constraint on all the field effects. The three fundamental forces electrostatic, magnetic, and gravitational, all use the same hyff, but just different information channels thereon, see part 4.3.

3 Conclusions

A conceptual model has been shown for cordus electromagnetism. The starting premise is that all fields are hyff, of one sort or another. Hyff are directional force lines that extend out into space from their basal particuloid, and where the force appears in pulses that travel outwards along the line (hyffons). Thus fields consist of a rapid sequence of discrete impulses of transient force, radiating out from a cordus at the centre. However we do not see this granularity at our level of perception. Instead we perceive fields to be smooth, continuous, and uniform in all directions. This is because of the en-masse effect of many particuloids being involved.

For a test charge in an electric field, the overall effect is a steady rain of hyffons that are individually small transient units of force. The overall effect is a smooth force. From the Cordus perspective, a static charge only generates an electrostatic force, without magnetism, because the hyff are straight outwards. However a moving charge *causes* bending of the e-hyff, and this is what we perceive as magnetism. Any moving mass generates curvature of the hyff, and these generate the magnetic field, except that neutral-charge mass has no observable magnetic field because it emits positive and negative hyff. Thus electrostatic forces are a position effect, while magnetism is a velocity effect. However the same basic structure, the hyff, is responsible for both.

Cordus electromagnetism is applied to explain the electric field surrounding a wire carrying current, the locus of moving test charges in a magnetic field, and the mechanism for how force arises in permanent magnets.

The contribution made by this paper is a description of electromagnetism that goes to the next deeper level: it can explain the underlying mechanisms for *how* the forces arise, where conventional theories do not go. Also, it provides a mechanism for fields to be granular *and* directional at the small scale, but smooth and continuous at larger scale. What is particularly valuable is that the overall coherency of the cordus concept, in that the same mechanics that resolve wave-particle duality can also be used to explain fields, i.e. the creation of a consistent conceptual framework.

The cordus explanation for electromagnetism is unorthodox in several areas. First, it dispenses with the need for additional particles, and conventional references to 'virtual particles' of any kind are thus re-interpreted as a hyff effect. Second, conventional theories tend to portray electric fields and magnetic fields with equal standing: they are interchangeable concepts. By contrast, Cordus suggests that the electric field is the fundamental effect, and the magnetic field is a derivative. Thus electrostatics is a reactive end position effect, magnetism a RE-movement phenomenon, and (yet to be shown) gravitation a RE-acceleration effect. Third, Cordus is unconventional in asserting that the electric field cannot be shielded, and that what looks like shielding is only localised neutralisation.

The results show that the Cordus conjecture can be extended to electromagnetic fields. Doing so permits novel re-conceptualisation of some fundamental paradigms of conventional physics. In particular, Cordus shows that it is conceptually easy to explain how granularity of the electromagnetic field arises at a sub-atomic level, and also how the macroscopic perception arises of fields being smooth. Furthermore, the cordus concepts of fields are important in what follows, when the composition of the vacuum is considered and gravitation is added to the model.