On the nature of the electron

- A light alternative to string theory

- The mathematics of reality

- Femtoelectronics: electron electronics

- Electro-pivot-magnetic nature of strong, weak and gravitational forces
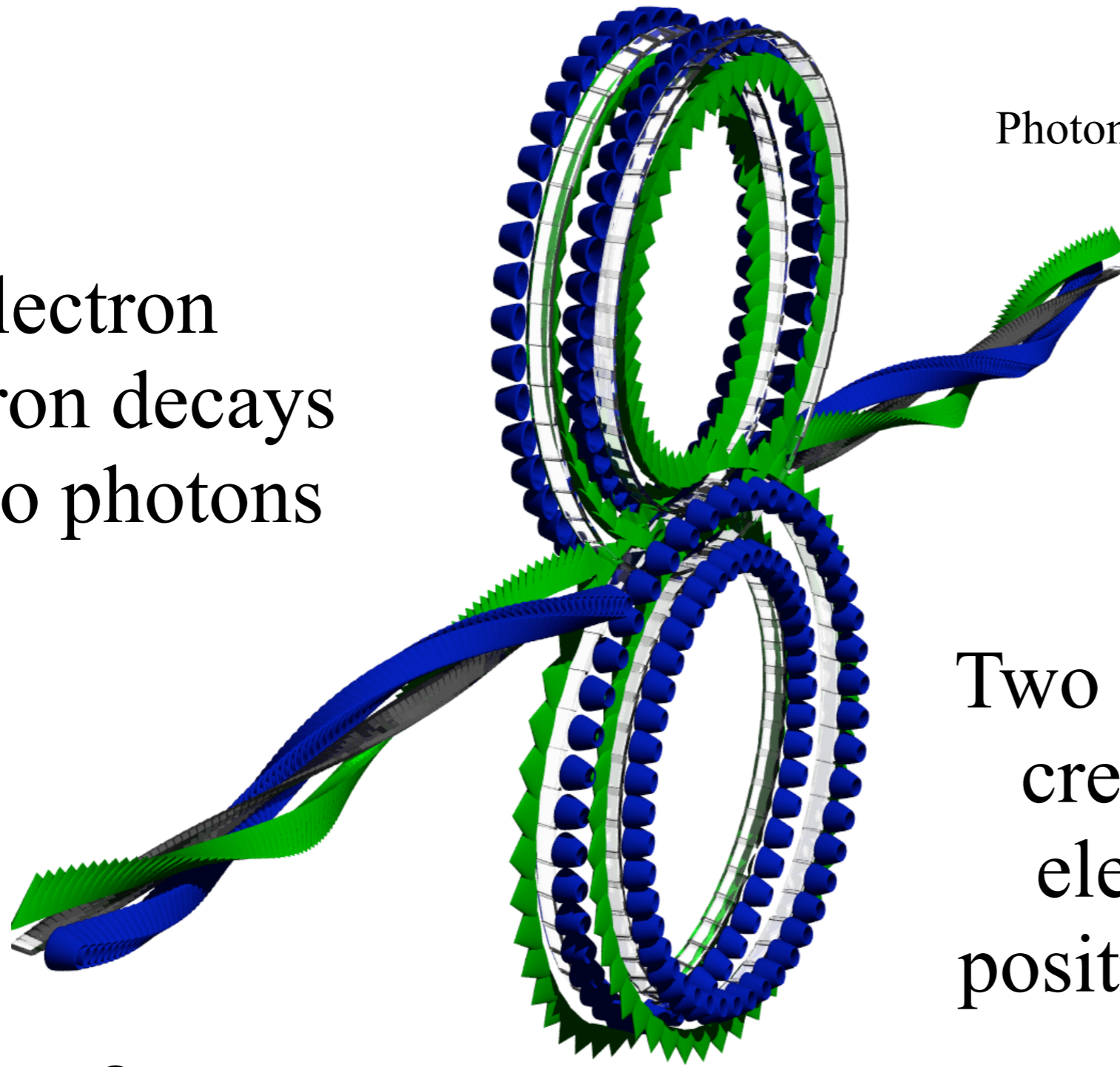
- The nature of everything else

John Williamson
Martin van der Mark

Thanks:

- Stephen Leary (wavefunctions+ lots)

- Phil Butler (introduction to the maths)

- Ariane Mandray and Michael Berry

- Tim Drysdale and John Weaver (foils)

- Grahame Williamson (rotation horizon)

The starting point: creation/annihilation

Photons/Loops not to same scale

Electron
positron decays
to two photons

Two photons
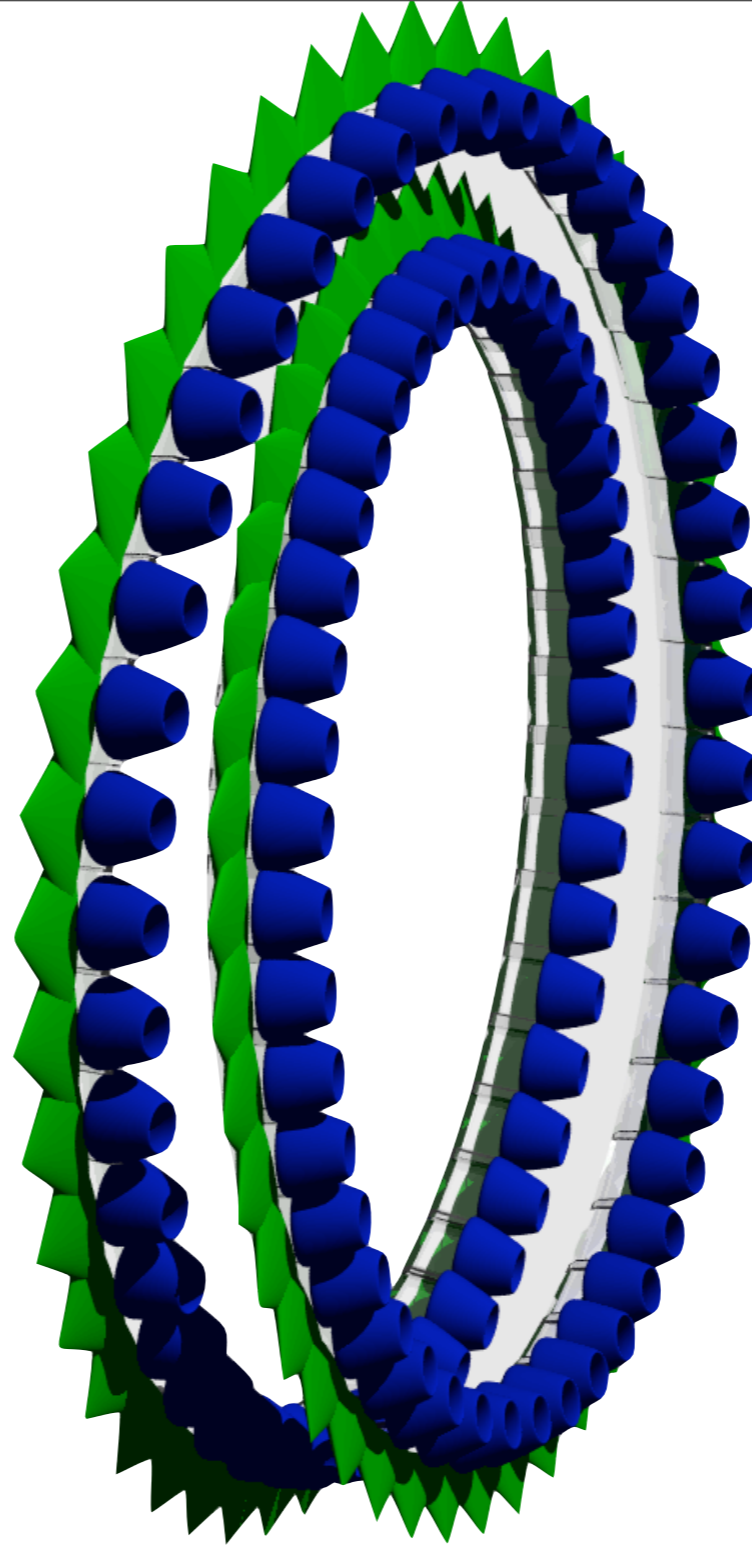create an
electron
positron pair

How?

Positron

Snapshot at creation

Tumbling toroidal topology

Single wavelength resonant harmonic purely electromagnetic self-recreating object

Heirarchy:
Fields
Vortices
Photons

Blades electric, hollow cones magnetic phase direction space-time bivector

Williamson/van der Mark
Semi-classical electron model[1]

- Assumed circulating photon: no forces

- Electron extended yet pointlike

- Calculated, charge, spin, g-2

- Derived uncertainty, exclusion principles

- Limited (or delayed) impact so far

[1] Ann. fond. L. de Broglie, 1997

Electron. Photon

Vortex - but not
in space as we
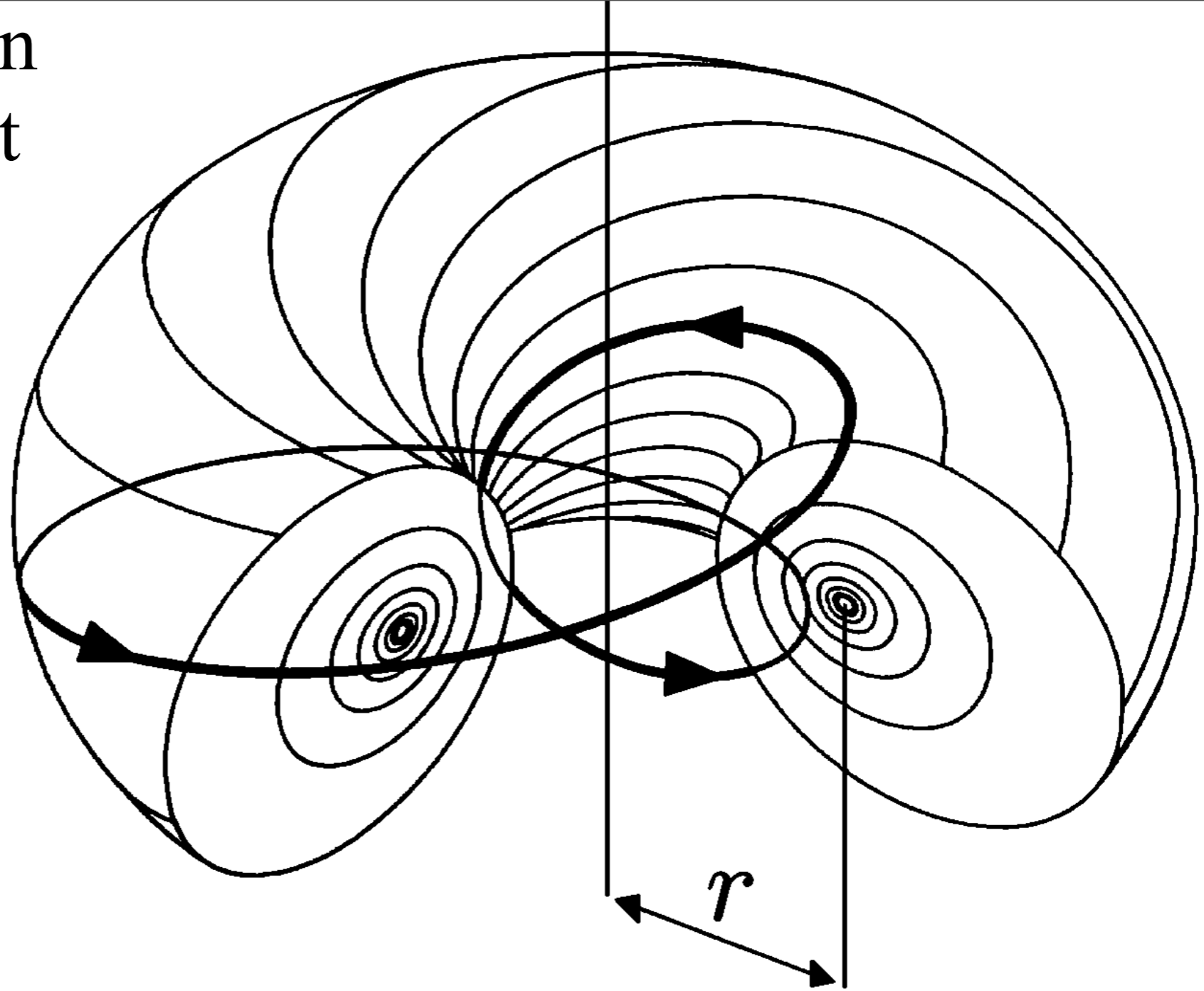know it

Small
is
large

Large
is
small

Wind
it up!

Figure 2:   *Schematic of the internal energy flow in the model. The lines of flow (geodesics) circulate twice around a family of nested toroidal surfaces before closing on themselves. The left-handed case is illustrated. For clarity, one complete double-loop path is emphasised. The toroidal structure is characterised by a length $r = \lambda_C/4\pi$.*

3 snapshots of field distribution for one path

Electric monopole magnetic dipole momentum density

Tumbling torus due to (angular) momentum conservation
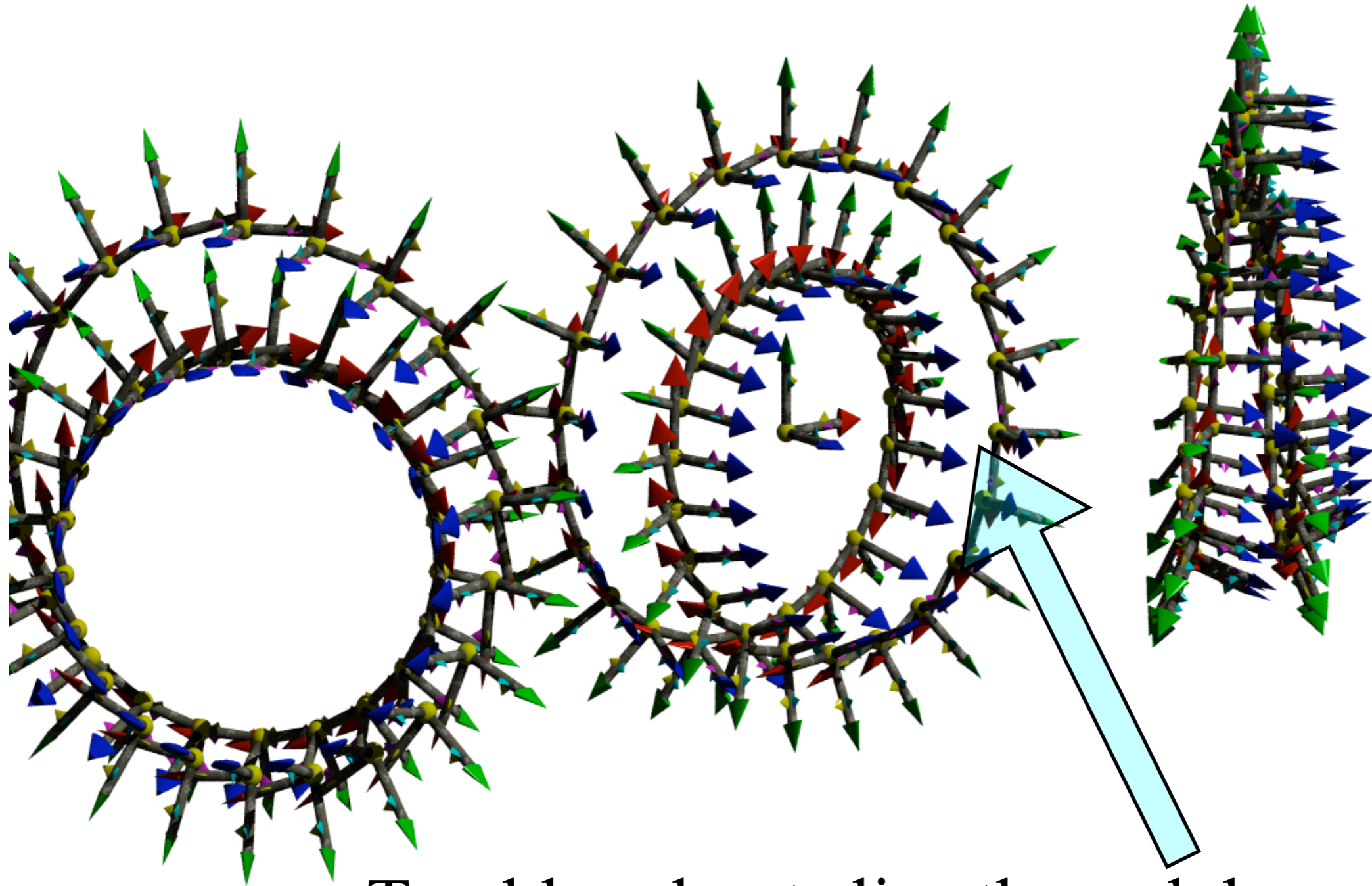
Tumbles about slice through here

Express in mathematics which best parallels reality

- Why? … To analyse something effectively one should use the proper form

- Complex algebra is too simple-reality is non-commutative

- Must handle relativity and support waves

- Use Dirac-Clifford-Minkowsky algebra

- 4D algebra of points, lines, planes, volumes

Represent 4 dimensions in Dirac gamma matrix algebra with Lorentz (+ - - -) metric

4D unitary basis $\gamma_0, \gamma_1, \gamma_2, \gamma_3$. (time space space space) gives 16 linearly independent unit basis elements under multiplication (or division), in this sense 16D.

The rules:

$$\gamma_0 \times \gamma_0 = +1, \; \gamma_1 \times \gamma_1 = -1, \; \gamma_1 \times \gamma_0 = \gamma_{10} = -\gamma_{01}$$

That's it! The rest is mere maths. One index things are directed line elements (space, time). Any element times itself gives a scalar. A line times a perpendicular line gives an oriented plane. Plane times its perpendicular (dual) plane gives a four-dimensional hedgehog. Abstract: works in any orthonormal system (including toroidal).

Reality not quite just 4D. More like (3*4 + 4)D

- The invariant scalar (1) Energy, mass

Squares to:

γ_0
- timelike vector (1) time, charge

positive

γ_3
- vector (3) space, 3-current

negative

γ_{12}
- spacelike bivector (3) mag field, rotation

γ_{30}
- timelike bivector (3) Elec field, momentum

γ_{012}
- timelike trivector (3) angular momentum

γ_{123}
- Hedgehog (1) ang mom source

γ_{0123}
- dual (1) emergency action (gauge)

But looks 3D! (4 3D spaces superimposed)

The key to the power of the algebra is that all elements transform **properly** (relativistically) with the correct four-dimensional commutation relations in any frame. The elementary process described by a vector derivative (infinitesimal division) is with respect to the ruler-clock of the appropriate observer (actor).

The 4-vector derivative (an infinitesimal quotient) means the spatial part (because it squares to -1) has opposite sign to the vector

$$d = \frac{\partial}{\partial x_\mu \gamma_\mu} = \partial_\mu / \gamma_\mu = \gamma^\mu \partial_\mu = g^{\mu\nu} \gamma_\mu \partial_\nu =$$

$$\partial_0 \gamma_0 - \partial_1 \gamma_1 - \partial_2 \gamma_2 - \partial_3 \gamma_3 = \gamma_0 \partial_0 - \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \vec{\nabla}$$

It inherits the proper transformation properties through the algebra and hence is a full covariant derivative in any frame . It is not passive since it implicitly defines the actor (observer) frame (relativity!).

Electromagnetism: start with the four-derivative of the four-vector potential

$$A = (A_0(t, \vec{x}), \vec{A}(t, \vec{x}))$$

The co-ordinates refer to the differential frame

we write the 16 $(= 1 + 3 + 3 \cdot 2 + 3 \cdot 2)$ terms of the full product dA as

$$dA = \partial_0 A_0 + \vec{\nabla} \cdot \vec{A} + \begin{pmatrix} \gamma_{01} \\ \gamma_{02} \\ \gamma_{03} \end{pmatrix} (\partial_0 \vec{A} + \vec{\nabla} A_0) - \begin{pmatrix} \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{pmatrix} \vec{\nabla} \times \vec{A}$$

This contains field components F and scalar component P, arising from the vector potential A

$$\mathrm{P} = \mathrm{d} \cdot \mathrm{A} = \partial_0 A_0 + \vec{\nabla} \cdot \vec{A}$$

Identify electric and magnetic field in the usual way

$$\vec{E} = -\partial_0 \vec{A} - \vec{\nabla} A_0 \ , \ \vec{B} = \vec{\nabla} \times \vec{A}$$

Thus we write the electromagnetic field as a set of oriented plane elements (bivectors)

$$\mathrm{F} = \begin{pmatrix} \gamma_{10} \\ \gamma_{20} \\ \gamma_{30} \end{pmatrix} \vec{E} - \begin{pmatrix} \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{pmatrix} \vec{B}$$

This reveals the proper form of the fields.
The magnetic field is no vector. It is often said to be an axial vector, though the concept axial is only strictly defined in 3D. The electric field is also no vector, though it looks like one under time projection.
Under a Lorentz rotation or boost the bivectors transform as fields, the vectors as 4-vectors, and the scalar is invariant

Setting the four-derivative of the field (24 terms) equal to the 4-current $\mathbf{dF = J}$ gives all of the Maxwell equations

$$\gamma_0 \vec{\nabla} \cdot \vec{E} = \gamma_0 J_0$$

$$\gamma_{123} \vec{\nabla} \cdot \vec{B} = \gamma_{123} J_0^m = 0$$

$$\begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \left(\vec{\nabla} \times \vec{B} - \partial_0 \vec{E} \right) = \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \vec{J}$$

$$-\begin{pmatrix} \gamma_{023} \\ \gamma_{031} \\ \gamma_{012} \end{pmatrix} \left(\vec{\nabla} \times \vec{E} + \partial_0 \vec{B} \right) = \begin{pmatrix} \gamma_{023} \\ \gamma_{031} \\ \gamma_{012} \end{pmatrix} \vec{J^m} = 0$$

Proper form, all at once, right signs, no dual

Pivotal term is the invariant scalar

The invariant scalar P is related to the gauge. The normal gauge is just its derivative. Often gauge freedom is used to introduce a phase (a wave) into a theory. We will not do that here. In the present context such an approach would be analogous to inventing the wheel and then using it as a flower planter.

We will leave waves to the coupled first order differential equations, and use P to confine light.

To see this fully one should look at the generalised Lorentz forces (big equations!). Time limited-several possible choices (all confining). Luckily one can see the effect already in the multivector momentum.

The invariant scalar P introduces confinement, mass and charge into pure field electromagnetism. Consider a field and a counter propagating field corresponding to a twisted mode or to pair creation. We have:

$$M_{field+scalar} = \frac{1}{2}(F + P)(F^\dagger + P^\dagger) =$$

$$\frac{1}{2}(\vec{E}^2 + \vec{B}^2 + P^2) + \begin{pmatrix} \gamma_{10} \\ \gamma_{20} \\ \gamma_{30} \end{pmatrix}(\vec{E} \times \vec{B} + P\vec{E})$$

Analogy
$$\Psi^*\Psi$$

With P zero have standard energy density plus Poynting vector. The P term introduces a radial (confining) momentum component and an extra (rest) mass. Its time derivative is a Poincaré force (there are more if generalise to full derivative). These are the forces required to generate the circulation required to generate charge.

Half integral spin because

$$L_{orbit} = |\vec{r} \times \vec{p}| = \frac{\lambda}{4\pi} \frac{U_{photon}}{c} = \frac{\hbar}{2} \ ,$$

- spin-statistics theorem

- Complete revolution after 720 degrees

- Most fundamentally: field configuration such that enormous energy cost unless spins antiparallel: exclusion "principle" is a strong force

Spin projection (SU(2))

Light on that most peculiar of quantum spin properties? Yes

Analogy: a stick through the spokes of the quantum bicycle

The third axis required to transform bivector field to trivector angular momentum is provided by the measuring process. Only a perpendicular axis will do, but the object "hunts" through all bivectors within a single cycle, very soon (order 0.01 attoseconds) there will be a match and presto! spin parallel or antiparallel.

Have to admit that cracking this one is personally very satisfying. Always bugged me!

If the electron is a purely electromagnetic loop, what about other particles?

- How?

- Consider "generations" as tighter (double, triple) loops

- "quarks" as overshooting loops transforming e.g. x to y

- only three quarks and quark-antiquark

Conclusions

- New generalised theory of electromagnetism, gives possible explanations for charge, half integral spin, the uncertainty and exclusion principles, the nature of electrons and quarks

- Further developments include the nature of photons and the strong and weak interactions

- No free parameters, so if it's right it's only just right. Very vulnerable to experimental disproof . Unless of course …

Beyond Maxwell

- The power of the maths gives hope of progress

- Einstein generalised force density product FJ: maths insufficiently potent. Dirac gauge (scalar) to introduce charge, but very simply. Anderson and Arthurs extra gauge (hedgehogs) to introduce angular momentum

- Need forces (or at least multivector momenta) not sure of "correct" route … choose one which works!

First dividend is that all 28 terms of Maxwell equations (4 derivative d of 6 field F = 4-current J) may be written as a single equation dF=J

Conventionally write $\qquad d_\mu F^{\mu\nu} = J^\nu$

but this is only half of Maxwell. To get other half (and signs) need to use dual field (see e.g. Jackson).
We will move to writing the field in terms of the vector potential A, dA = P + F, where P is some scalar (mass) term, and then multiplying by another field dA.d(dA). Different colours refer to the fact that the 4-vector potentials may be distinct and the 4-differentials may refer to different (observer/actor) frames. This equation has 1024 terms. No (good) chance unless all signs are right. This is where Einstein got stuck!
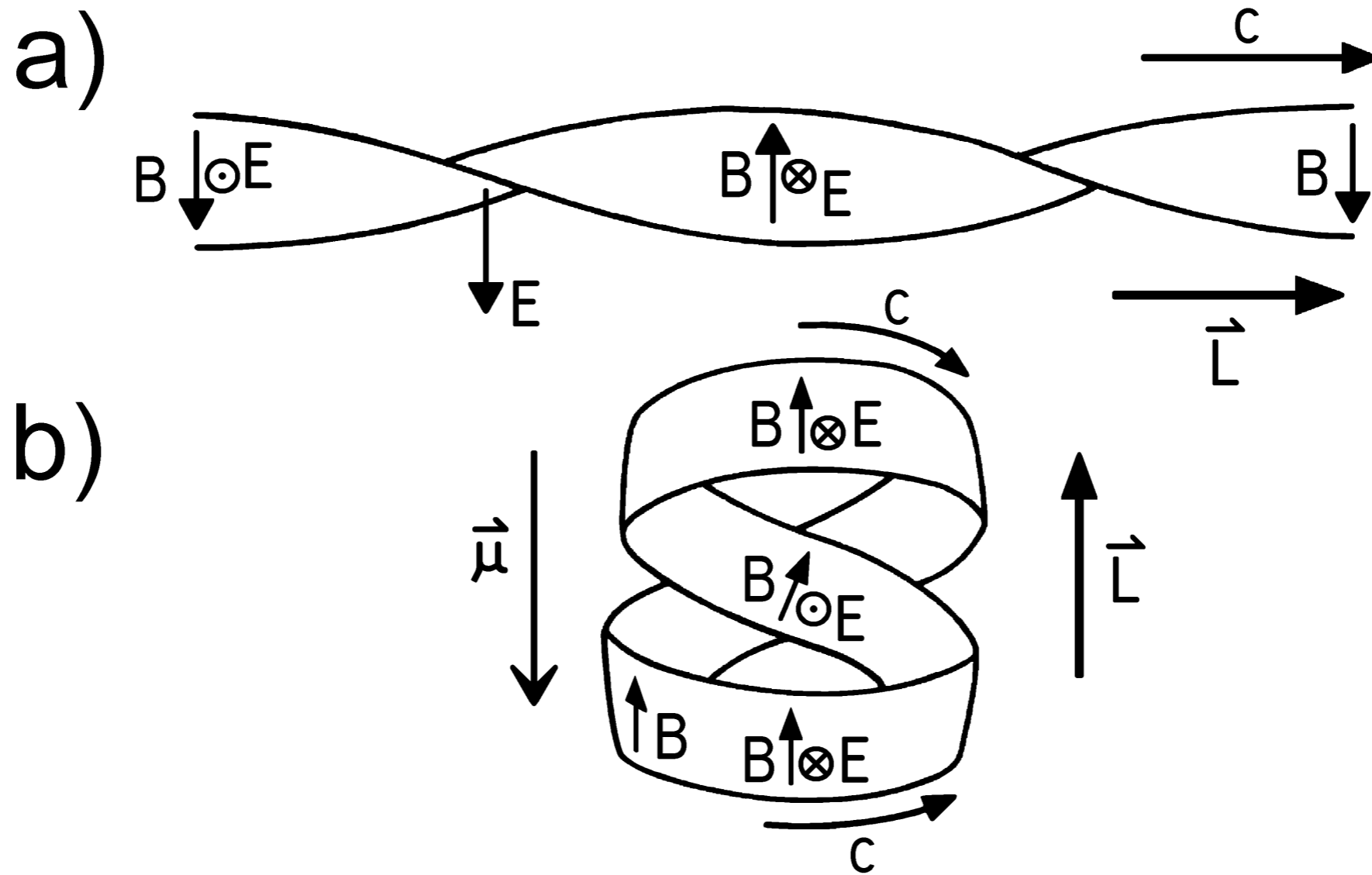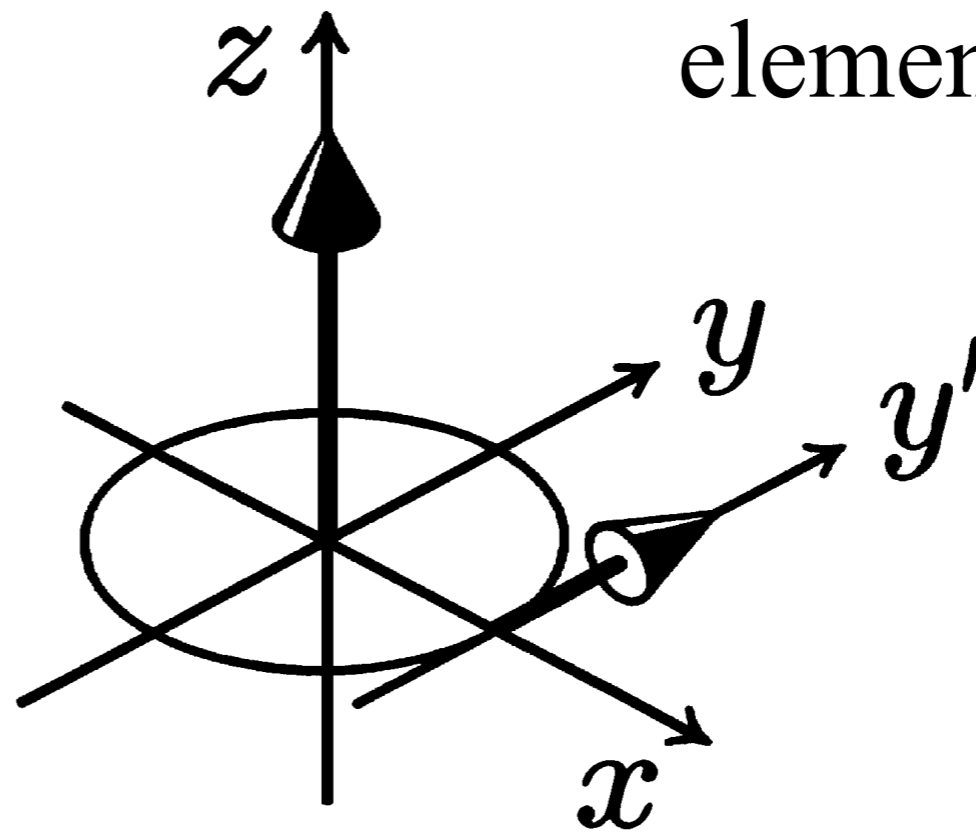
Figure 1:   **a)** *Twisted strip model for one wavelength of a photon with circular polarisation in flat space. The $\vec{B}$-field is in the plane of the strip and the $\vec{E}$-field is perpendicular to it.*
b) *A similar photon in a closed path in curved space with periodic boundary conditions of length λ_C. The $\vec{E}$-field vector is radial and directed inwards, and the $\vec{B}$-field is vertical. The magnetic moment $\vec{\mu}$, angular momentum $\vec{L}$, and direction of propagation with velocity c are also indicated.*

The quantum bicycle^{©®}

Rotations of rotations (of rotations)
Harmonic: cogs and gears

Offset related to
elementary area

not in space,
but of space/time

May also use scalar P (pivot) to introduce a (bare) charge directly into Maxwell

d(F+P) = 0 (see Dirac)

$$\gamma_0 \vec{\nabla} \cdot \vec{E} = -\gamma_0 d_0 P$$

$$\gamma_{123} \vec{\nabla} \cdot \vec{B} = 0$$

$$\begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \left(\vec{\nabla} \times \vec{B} - \partial_0 \vec{E} \right) = - \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \vec{\nabla} P$$

$$- \begin{pmatrix} \gamma_{023} \\ \gamma_{031} \\ \gamma_{012} \end{pmatrix} \left(\vec{\nabla} \times \vec{E} + \partial_0 \vec{B} \right) = 0$$

Nice, but not enough ... need forces

A general force equation may be derived from the 4-derivative of M. This appropriate for particle in box or pair creation. For single particle rotation FdF better.

$$M_{field+scalar} = \frac{1}{2}(F + P)(F^\dagger + P^\dagger) =$$

$$\frac{1}{2}(\vec{E}^2 + \vec{B}^2 + P^2) + \begin{pmatrix} \gamma_{10} \\ \gamma_{20} \\ \gamma_{30} \end{pmatrix} (\vec{E} \times \vec{B} + P\vec{E})$$

The effect of the scalar term is to introduce a mass, and to give rise to an additional, inwards directed component to the momentum. This is the term needed to give confinement. A circulating oscillating field gives rise in the usual way to a quantised system.

Generations and particle masses

The confinement of energy constitutes a mass (see e.g. van der Mark "Light is heavy".

Conjecture: Inertial mass arises from possibility of interactions from rest of universe (Mach's principle).

Electron is a single wavelength photon vortex: what if we double the loop? Is this the next generation, a muon?

Particle mass-ratios

Previously had two strands looking in each of three dimensions, now have four. For an interaction need to confine energy. For single turn (electron) have 1 potential box (pair of strands in each dimension).

Next turn: have 4 strands and hence 6 possible pairs giving 216 potential boxes. Hence next particle should have 216 times electron mass (muon). Turn again: gives 6 strands, combinatorics gives 15 pairs so 3375 times electron mass (tauon). Mass ratios both correct to few percent.

Be wary: could be blind chance … needs investigation of other particles.
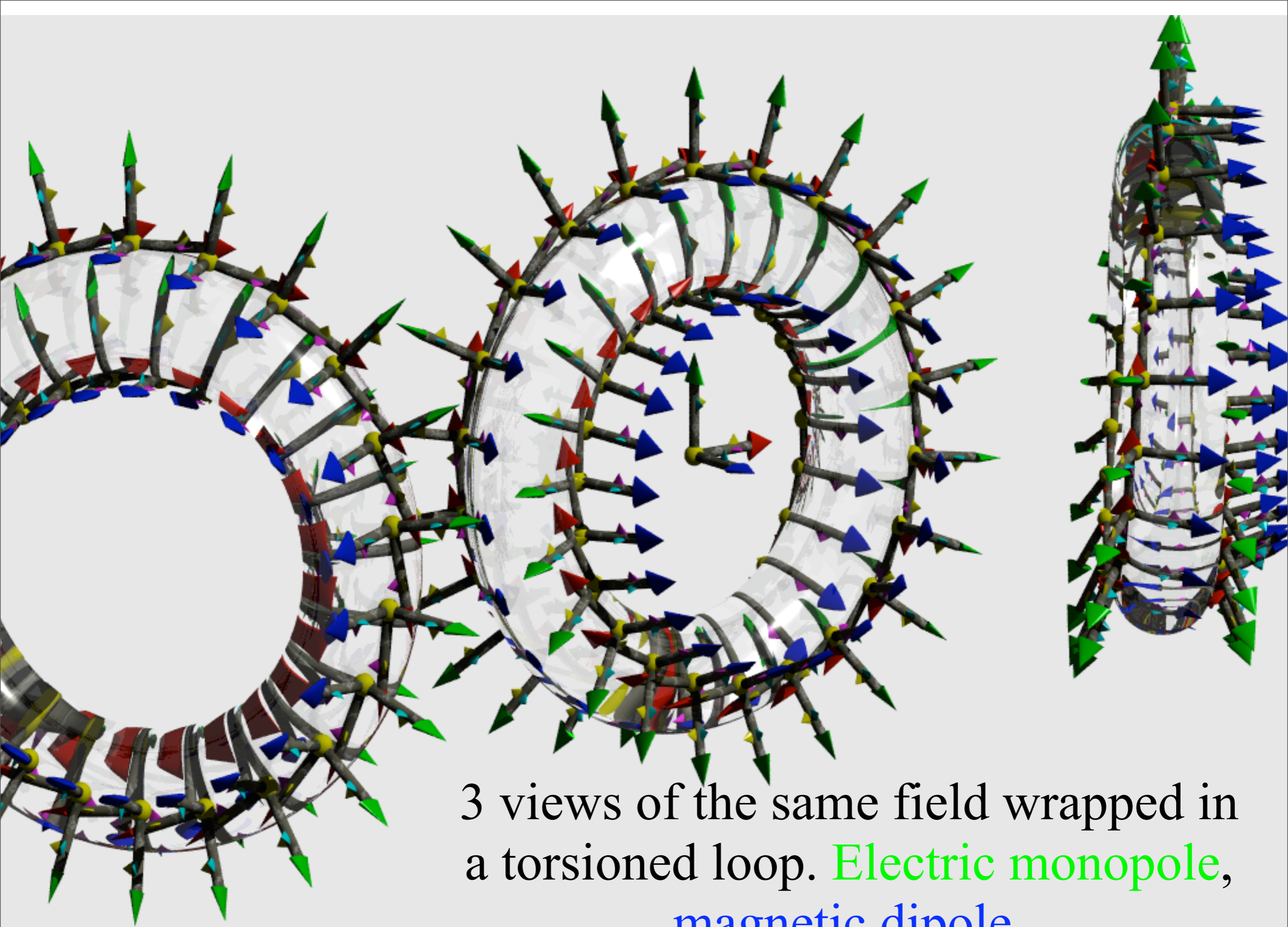
3 views of the same field wrapped in a torsioned loop. Electric monopole, magnetic dipole.

So what does it all look like? Can one model an element of momentum. Pick a point where E and B are defined in one direction in each of their 3D subspaces. Model momentum, but add additional curvature due to LE term. Mark phase as a torsional rotation about the path. One obtains:
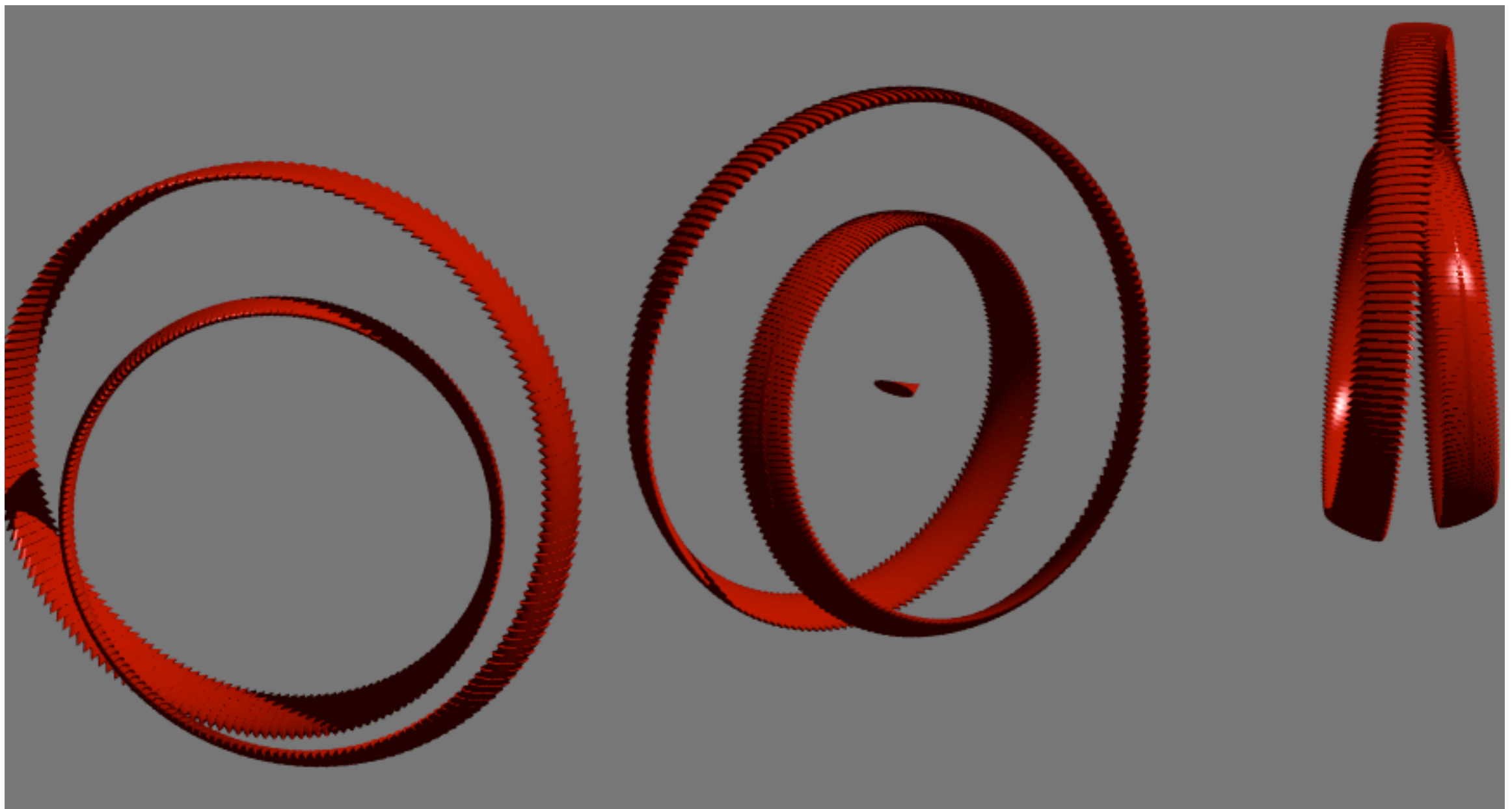
Uncertainty principle

- The phase(s) of the electron are unknown

- Varies ± c at twice Compton freq

- Reproduces all features of standard uncertainty relation except energy uncertainty limited to electron mass (see Hestenes "Zitterbewegung interpretation of quantum mechanics")

Mysteries

- Charged from chargeless

- Fermions from bosons

- Pointlike yet extended

- Lepton number, CPT, rest mass, g-2, generations, quantum spin ...

- The whole zoo - many particles many properties ...

Products and quotients (differentials) generate complexity from simplicity

Multivector:

scalar +vector+booster+rotor+trivector+quadrivector

$$\Psi = s + v + b + r + t + q$$

$$\Psi = s_0 + \gamma_{\gamma 0} v_0 + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{pmatrix} \vec{v} + \begin{pmatrix} \gamma_{10} \\ \gamma_{20} \\ \gamma_{30} \end{pmatrix} \vec{b} +^{to}$$

$$\begin{pmatrix} \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{pmatrix} \vec{r} + \begin{pmatrix} \gamma_{023} \\ \gamma_{031} \\ \gamma_{012} \end{pmatrix} \vec{t} + \gamma_{123} t_0 + \gamma_{0123} q_0$$

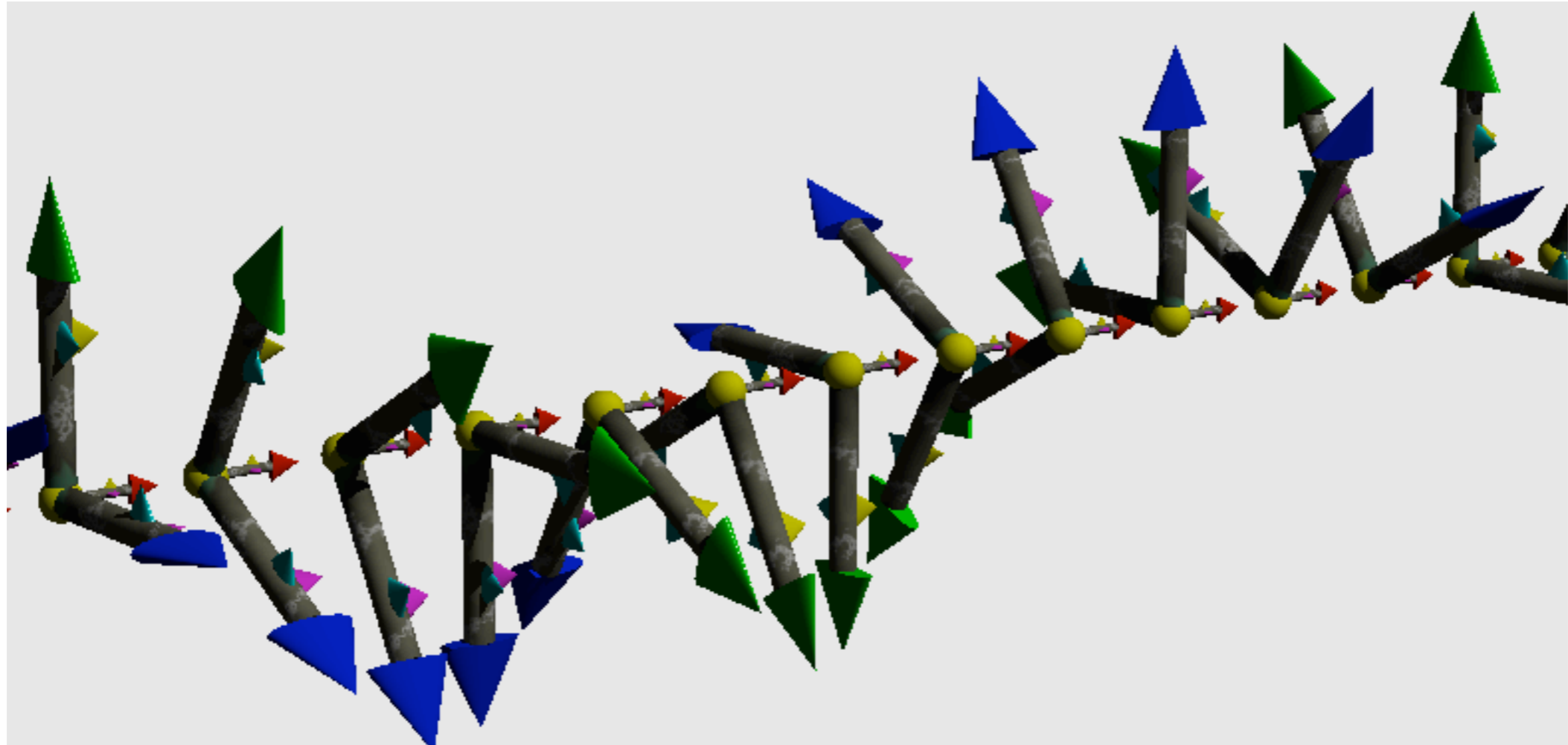Note again groupings into 3D and 1D elements

From Semi-classical Model of confined photon get charge, spin and g-2
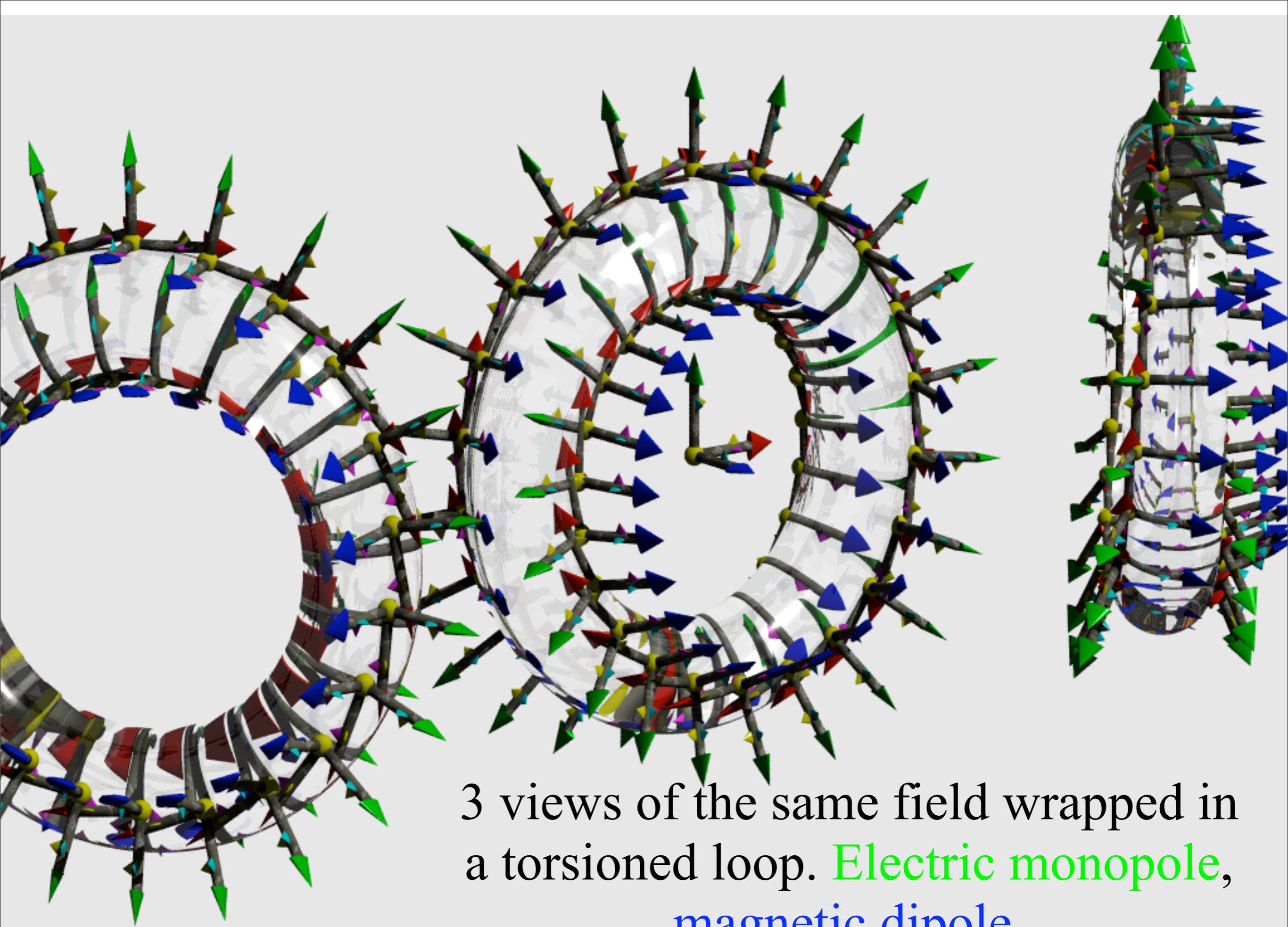## (Williamson, van der Mark, Ann fond L. de Broglie, 1997)

$$q = \frac{1}{2\pi}\sqrt{3\varepsilon_0 \hbar c} \approx 0.91e,$$

$$L_{orbit} = |\vec{r} \times \vec{p}| = \frac{\lambda}{4\pi}\frac{U_{photon}}{c} = \frac{\hbar}{2},$$

$$\mu_d = \left(1 + \frac{\alpha'}{2\pi}\right)\frac{q\hbar}{2m_e} = sg\mu_q,$$

Model of Electric, Magnetic and momentum for one wavelength of a photon

3 views of the same field wrapped in a torsioned loop. Electric monopole, magnetic dipole.

Deep questions (1-1-92)

- h

- e

- Quantisation of e

- Mass

- Spin

- Pauli principle

- Uncertainty principle

- CPT

- Boltzmann constant

- Non-existence magnetic monopoles

- Gravitons

- Allowed black body modes

- Bell inequality

- Red shift

- 3K background radiation

- Origin of universe

- Flatness of universe

- Conservation laws (times n)

- Energy ... mass

- Momentum .... Force

- Angular momentum

- why is c constant?

- and why 300 000 000 m/s?

- wave-particle duality

- measurement collapse

- Baryon number (6)

- why only qqq and qq*

- Lepton number (3) (3 generations puzzle)

- quarks

- gluons

- neutrinos

- coupling constant EM

- coupling constant EW

- coupling constant S (plus why running coupling constant)

- Postulate of equivalence

- nature of space and time

- First law of thermodynamics (Energy conservation)

- Higgs

- Spontaneous symmetry breaking

- Mach's principle

- Poincaré stresses

- Why 4-D?

Where am I?
Here and now

- Observable universe series of concentric spherical shells centred on the observer

- Shells characterised by lightspeed

- Include immediate locality (few ns ago) sun (8 mins ago), Alpha centauri (4Yrs) ...edge of universe (order 10 billion yrs ago)

- Corollary: the real universe is "imaginary", only time is "real"