

## On the Radiation Origin of Matter

Riadh Al Rabeh

Department of Mech. Eng., University of Basra, Iraq (retired)  
*Present address: 37 Surrey Av., Cheltenham, Gloucester, UK*

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### Abstract

Pair annihilation experiments showed that two massive anti-particles can turn into pure radiation, while pair production experiments showed the reverse. Electron-positron(e-p) pair processes are accurate, and reversible. This is taken to indicate that matter is nothing more than trapped/condensed radiation and radiation in turn is only an evaporated matter with a condensation factor given by Einstein equation  $E=mc^2$ . We take the trapping to be in the form of an EM topological soliton [4], in which radiation goes round in closed loops. This is used to explain the emergence of the matter-particle specific attributes like; rest-mass, gravity, intrinsic spin and dipole moment. These are due to radiation circulation inside the soliton and the fact that EM radiation itself carries mechanical as well as electrical attributes in the form of momentum  $\mathbf{p} = \mathbf{S}/c^2$ , and energy  $\mathbf{S} = \mathbf{E} \times \mathbf{H}$ , where  $\mathbf{S}$  is the pointing vector. This construct results in a considerable simplification of many of the intricate problems of radiation- matter interactions and makes them trivial. A particle moves by absorbing momentum from radiation and gains mass instead if the latter is from opposite directions with zero net momentum, and all energies including electric and gravitational potential energies, are just EM radiation. Given extra energy, the e-p pair can trap each other instead of annihilating. This produces the first and smallest *neutral* atom- the positronium. Such atoms can further unite via the Van-der-Val dipole forces to create the rest of the elementary particles up to that of the neutron. On losing one electron and subsequently trapping it back by further energy loss, the first highly stable structure- the hydrogen atom is created together with a stable proton. Many hydrogen atoms can further unite via the same forces to create the rest of the stable and unstable elements of the periodic table. Stability is determined by the specific particle configuration together with its energy of

formation being a minimum. The seat of the black swan, butterfly, fractal universe, missing antimatter and the arrow of time concepts, all have simple answers as a result.

**Keywords:** Origin of matter, attributes of matter, energy conversions, Hopf's mapping, topological solitons, fractal universe, principles of physics

## 1 Introduction

That part of ordinary mass comes from motion energy was first talked about by Stokes in 1863 in connection with particles in inviscid fluids acquiring extra mass upon motion. But it was Einstein who was first to state a complete equivalence between rest mass and energy in his famous formula  $E=mc^2$ . It remained however, unclear of the physical process by which such a transformation can take place, as matter and energy looked and felt very different to any observer. Pair creation and annihilation experiments in particle physics then gave the strongest support to the idea of complete equivalence. Here matter particles transform to pure radiation and back in a process that is very accurate and infinitely repeatable. We propose here the soliton model for such conversion and use it to show the emergence of the fundamental matter-specific attributes; mass, charge, spin and a magnetic dipole moment from radiation. We start by first giving a simple definition of space-time and its connection to matter and radiation. Then use it to give simple explanation to many intricate problems of matter-energy interactions, for any particle size from that of the electron and up to the rest of the elementary particles and continue to cover the rest of elements of the periodic table. Big questions like the seat of inertia and the reason for the fractal appearance of the universe can find simple explanations then. This work builds on and refines the author's initial work on the subject in [6].

## 2 Space-Time

The minute the Brownian motion was discovered we should have realized that motion and not rest should be taken as the normal state of particles and that of the world. Motion is the main variable by which interactions should be described not separate position and time. But motion or velocity has the units of space and time( $m/s$ ) locked in an inseparable manner. Thus space-time appears clearly here as the main component of everything around us. But motion requires something to move, which is a mass. This then says that mass-space-time is in fact the fundamental variable that is needed to describe the world, which is nothing other than *momentum*. Newton for example spoke only of 'the quantity of motion' for momentum, and the time change in it for force. That was abandoned in favor of the more intuitive (and more confusing- like having fictitious forces) force concept. Since mass can have an electric charge too, we still

have to add this to the picture for completeness. Since we know that momentum is strictly conserved, we see that space time is conserved too- i.e. it can't be created or destroyed.

The simplest thing that carries all the above units is electromagnetic(EM) radiation. We accordingly take radiation as the substance needed to describe the world or the true representative of space-time and also note that it also obeys momentum conservation. Accordingly, we can say that anything that can't interact with radiation with its electrical and mechanical attributes, can't be part of our space-time. A soliton mechanism for radiation to matter transformation discussed below, leads radiation self-trapping and circulating in closed loops. This is then shown to lead to the emergence of all the attributes of matter; mass, spin, charge and magnetic dipole moment. It should be said here that radiation alone can't feel the space or the time as these are created first upon condensation/circulation to become matter. Time is created by the *number* of turns made in a loop of trapped radiation, and distance is created as radiation is sent from one particle to the other (the e-p pair for example) while counting such rotations, and knowing that the speed of propagation is an all-time constant. Note that this is exactly how we define the *second* and *meter* in the international standards. Since rotation is a number, time becomes a *scalar* variable, and the number of counts is always increasing giving the so called *arrow of time* concept.

### 3 Pair Production & Annihilation Experiments

These experiments are some of the most revealing experiments about the origin of mass. The clarity of such experiments is clouded however by the unfortunate use of terms like 'anti'-matter- when what we mean is matter but with attributes carrying the negative sign of those of 'proper' matter. From these experiments we learned that a pair of two particles of oppositely signed physical attributes can annihilate to radiation and nothing else. At the same time, radiation of an appropriate and equivalent energy can create the electron-positron pair in the presence of a nucleus. The nucleus acts as a catalyst only and doesn't take part in the energy counting. Further, this process is reversible and infinitely repeatable. It is the clearest indication that matter is a condensed form of radiation, and radiation is nothing other than evaporated matter.

For radiation to be called evaporated matter however, it needs to carry matter attributes too. This is the case indeed, as radiation carries electric, magnetic, as well as its mechanical attributes. It has an electric and magnetic field vectors normal to each other and to the direction of propagation. Also a momentum vector and energy intensity and pressure derived from the Poynting vector,  $S = \mathbf{E} \wedge \mathbf{H}$ , where E,H are the electric and magnetic field strengths in the direction of propagation of a plane EM wave. For a differential small section of the wave-front, all waves are plane. The momentum intensity in radiation is given by;  $S/c^2$ , and the energy by  $S/c$ . These formulae have been continually checked and found correct in every matter-radiation exchange, be it expe-

rimental or theoretical. Accordingly, if matter absorbs radiation it will absorb momentum with it that increases its speed. It will also increase its mass without a change in speed if the absorbed radiation is from opposite directions with a zero-net momentum. These facts have been observed in particle experiments wherein excess radiation to that needed in pair production shows up in the form of kinetic energy in the flying particles.

## 4 Forms of Energy

Energy and radiation refer to exactly the same thing, which is EM radiation. This is why we can convert energy from one form to the other easily and without a loss. Heat energy can't be converted all to kinetic energy however, as the process is limited by the law of entropy. This we discuss in the next section to see why. But at least we know that the converted portion is achieved without a loss. That is if we convert the kinetic energy back to heat, we get back what was taken away exactly. Next, we claim that all energies are radiation and only exist as motion/kinetic energy. To see this, remember first that whenever we mention a mechanical term like force, momentum and energy we are tacitly implying the existence of a mass in the picture. The force between two electrons for example, is a function of the electric charges and the separation distance only, and no mass is mentioned. But if the force is to move anything, it is the mass of the electron. A force on a pure charge is not defined.

If we try to push/hit one matter with another to move it, we know that the molecules do not touch in the process. They affect each other via the electric field Coulomb forces. But as we need to accelerate in order to move, the problem changes from a static field to an electromagnetic or radiation forces as per Maxwell equations. Thus, when two billiard balls collide, the fast ball decelerates on reaching the other, emits EM radiation with momentum that is received by the slower ball causing it to move! We note next that potential energy is radiation too. As given earlier, every particle in nature is moving and the smaller it is the faster it goes. Inside the atom, the speed becomes a sizeable fraction of  $c$ . To explain the increase in kinetic energy using a stored (no motion) potential energy as from a compressed spring or the explosion of a chemical compound for example, consider this analogy; imagine steel balls rotating frictionless inside a circular tray, restrained by the edge. If the edge is to collapse, the balls will fly away with immediate and considerable kinetic energy. The motion of the molecules of the spring can be thought as similarly restrained within the molecular structure playing the role of the tray walls. Upon releasing the spring, the structure partially gives-in causing the release (transfer to be more accurate) of kinetic energy and causing a motion in the attached parts. As shown below, gravitational force is a direct consequence of momentum conservation and motion. Hence gravitational potential energy has a radiation origin too.

## **5 A Modified Definition of Entropy**

It is important to discuss entropy here because heat energy can't be converted fully to mechanical energy/motion as mentioned above, which can cast some doubt on the assertion that all energies are just radiation. Entropy is normally defined as a measure of the degree of chaos in a system. Or it is the total of possible configurations of a system in the formal definition. The theory says that the degree of chaos remains constant or increases in any isolated system interaction. When it is maximum, no more energy can be extracted from the 'moving' particles of the system. This is experimentally true of course but we need an explanation within the picture we are constructing here. We can instead redefine entropy as the degree of 'uniformity' in the system. That is; systems go towards full uniformity or stay the same as they interact and this would be the case of maximum entropy. When the system is all uniform, it is not possible to extract work from it, as doing so requires a difference and a driving potential to do work, which is clearly not there. Maximum chaos thus corresponds to maximum mixing, and it produces maximum uniformity. That is why in fluid mechanics for example, the maximum state of turbulence is called 'homogeneous' turbulence.

With this understanding it is possible to see that thermal energy(motion/agitation) must flow from hot to cold and never in the opposite direction. It is because fast-moving particles can increase the speed of slow-moving particles via interaction, but the reverse is clearly not possible. With time, this leads to colder(slower) particles becoming hotter and hotter than average particles becoming cooler- till a final uniform speed(temperature) is reached. This can be reversed only if there is an additional (external) energy input.

## **6 Momentum and Energy Conservation**

The conservation of these two quantities is a pillar of modern science. The origin of the conservation laws can be traced to a simple statement regarding a critically balanced universe. We could say that the universe is so critically balanced that moving one mass to one direction requires doing the opposite in the opposite direction- so that the center of mass remains unchanged. This idea of a critically balanced universe has been felt by humans very early on and cropped-in in many myths and sacred books. One myth says that the world is critically balanced on the tip of the horn of a bull (a god in the ancient times) and earthquakes happen as it is jolted from one horn to the other. The widely used symmetry of space doctrine in modern physics is an equivalent statement. This balancing is a 'god given' thing- so to speak and it is so powerful a law that you can't move a single electron to one side without moving another to the opposite side to keep the balance. It applies to radiation as well as matter.

In mathematical terms this amounts to saying;  $\sum m dx = 0$  along any line in space, where  $m$  is a constant mass and  $dx$  is its displacement from the center. Differentiating along time gives;  $\sum m v = \sum p = 0$ , along any line, where  $v$  is velocity and  $p$  is momentum. Repeating the same again gives;  $\sum m a = \sum f = 0$ , along any line, where  $a$  is acceleration and  $f$  is force. This shows that conservation of momentum  $p$  and the equality of action and reaction on  $f$  are only consequences of the critical balancing/symmetry of the universe. This is also the essence of the Mach principle or the effect of distant masses, since to move a *single* electron to one side you need to move the rest of the universe in the opposite direction. Since momentum is conserved, the integral of momentum along the line of motion is conserved too. This leads to conservation of kinetic energy since for constant  $m$ ;  $m * E = \int p \cdot dp = 0.5 p^2 + \text{const}$ . Since  $p = mv$ , we get;  $\Delta E = 0.5 m v^2$ .

## 7 Emergence of Gravity and the Fractal Universe

If momentum is conserved, Newton prove that the orbit of two isolated particles must be planar. Then Bertrand theorem showed that if momentum is conserved and the motion is in a plane, the forces between such particles must be either of the inverse square or the space spring form. That is;  $f = k/r^2$ , or  $f = kr$ . The space spring form or Hook's law force can be shown to be the limiting form of the inverse square force (or any other force for that matter like a tangent line) when the displacements are confined [5,7]. Since the inverse square is associated with Newton's gravitational force, we see that gravity is another consequence of the momentum conservation or the critical balance or the symmetry of the world ideas. We note also that this process is kinematical. The law of motion  $f = m a$ , can be cast as;  $F = f/m = a$ , where  $F$  is force per unit mass along any line. This is just the acceleration and appeared here as a pure kinematical quantity. Thus, the inverse square is a description of the path/orbit taken by a mass in orbit if momentum is conserved. This way we have (as in GR); the presence of masses in a certain region is the only factor that determines the *path* of motion. The difference is that we have in the Newton theory a nonlinear function for acceleration is happening in a flat space, whereas GR assume a linear/geodesic function for the path but in a nonlinear space-time.

Now, as the inverse square laws of gravity and electricity have the form of a power law  $f = kr^n$ , and as these laws control every process in the universe, it is natural to expect that the properties of such law will be reflected on other processes. For a large number of particles, we look at the probabilistic structure of the outcome from this law and make use of its probability density function. For this distribution and for  $n < -2$ ,  $n < -3$ , the distribution doesn't possess a first or a second moment (mean and variance) respectively. This says that there is no typical mean or variation to events in the world-leading to the possibility of the very large and very small all being possible with considerable probability. This allows for the so called 'black swan' and 'butterfly' type effects.

Further, a property of this law is that it is scalable since,  $f(ar) = a^n r^n = a^n f(a)$ . This says that the laws of physics don't change in shape with scale. In other words, the laws that apply to the femto- scale also apply to the Tera- scale and to our-scale too. This is the seat of the fractal appearance of the universe that can be observed in all sizes. This also leads to the comforting thought that to do laws and rules we only need to search in our scale of the universe, and we would be confident they will be equally applicable to all other scales as long as we are sure that momentum is conserved. One particular example is how the space spring of QM for tiny particles comes out as a special case of the inverse square law of Coulomb at conditions of confinement and crowding [5].

## 8 The Emergence of Matter-Specific Attributes

We now discuss the appearance of matter attributes like rest mass, electric-charge, intrinsic-spin and the magnetic dipole-moment attributes as a result of radiation condensing into matter. An advancing EM plane wave can be represented by three vectors. Note that as all curves are flat for a small segment, all waves are plane on a small region too. Momentum  $\mathbf{p}$  along the propagation direction and Electric and magnetic field vectors  $\mathbf{E}$ ,  $\mathbf{H}$  are normal to this and to each other. If the EM wave is trapped between two mirrors as in lasers for example, we see the immediate appearance of rest mass given by the Einstein formula applying to a trapped radiation. The trapped wave also needs to be a standing wave in order to survive destructive interference with itself. The momentum vector  $\mathbf{p}$  will be along the line of the laser and the  $\mathbf{E}$  and  $\mathbf{H}$  vectors normal to it.

Now imagine the trapping happens by going round a closed loop. In this case no mirrors are needed, and it would be self-trapping. That such arrangement is possible is the subject of the next section. As we have a trapped energy, we have a corresponding rest mass. Then as the momentum vector is now in the circular direction, this gives rise to the intrinsic spin of a particle. The  $\mathbf{E}, \mathbf{H}$  vectors are now normal to the circular/circumferential direction. The magnetic field  $\mathbf{H}$  vector can be normal to the loop surface giving rise to the *intrinsic magnetic dipole moment*. It is in-line with and has the direction of the intrinsic spin vector. The  $\mathbf{E}$  vector would then be radial. A radial field has a non-zero divergence and by Gauss's theorem equals to the enclosed charge  $q$ . This shows how the four matter attributes can directly emerge from an EM wave if it is trapped by going in closed loops, see Fig (1).

## 9 The Soliton as a Model for the Electron

The existence of an EM soliton shows the possibility of EM radiation to self-trap by going into closed circular paths while still going at the vacuum speed of light. Few things need to happen here. First the wave needs to end up as a standing wave so as not to annihilate itself- i.e. the path must be closed/repeatable. Then the process should

create two separate solitons running in opposite circulation- that is a soliton and an anti-soliton like matter and anti-matter, and like vortex and anti-vortex in fluids. This is required by angular momentum conservation. The third thing is that we need something that deflects radiation to go round and produce a particle (soliton) pair. That is what happens in fluid mechanics for example. To create vortices, we need an obstruction in the flow. In particle physics, a pair production of particles from radiation requires a nucleus to provide for direction changing from linear to circular. This is necessary in theory as the momentum of the resulting particles need to be provided from outside to complete the creation. The obstruction however neither takes nor gives energy in the process and can truly be called a catalyst. This can also be imagined like a *molding/seeding* process- since a seed is needed to start, and this can provide an explanation for why all electrons are exactly the same- a question put long before by Feynman (as stated in his Nobel prize award lecture). It is because they come from the same mold, very much like all water crystals are the same.

Now, Maxwell equations are linear and hyperbolic. They can generate an advancing wave but not circulation like that in a soliton. Experimentally however, people working in plasma physics and in nonlinear optics did notice the appearance of soliton structures, in which the wave condenses and moves as a single unit. This says that while we can't derive the soliton equations directly from the normal Maxwell equations in empty space, there must exist another way to do it and get these results. This is what was done in [2] by taking an equation of a conserved quantity in EM like that of the magnetic vector potential and the helicity of the magnetic field, then use a geometric transformation to change to spherical coordinates, then test if it satisfies Maxwell equations. The stereographic projection is used in this case. The next step is to check the outcome and examine the characteristics of the soliton.

The helicity of the magnetic field is a topological charge density and an integral of motion in the MHD of a 'perfectly' conducting fluid. It is given by the volume integral;  $I = \int \mathbf{A} \cdot \text{curl} \mathbf{A} \, d\tau^3$ , where  $\mathbf{A}$  is the vector potential. If two magnetic field lines are linked, this integral is proportional to their linkage coefficient, which is the number of times one is twisted around the other [2]. Taking  $\mathbf{A} = A_j$ , where  $j=1,2,3$  to be the components of  $\mathbf{A}$  along the Cartesian coordinates  $x_1, x_2, x_3$ , gives the components of this vector potential and the corresponding magnetic field strength  $\mathbf{H}$  as;

$$A_1 = \frac{x_1 x_3 - x_2}{2(1+x^2)^2}, \quad A_2 = \frac{x_2 x_3 - x_1}{2(1+x^2)^2}, \quad A_3 = \frac{2x_3^2 + 1 - x^2}{4(1+x^2)^2} \quad (1)$$

$$\mathbf{H} = \text{curl} \mathbf{A} = \frac{4\mathbf{A}}{1+x^2}, \quad (2)$$

where  $x = x_1^2 + x_2^2 + x_3^2$ .

The square of the magnetic field strength (a scalar) is *spherically symmetric* and given by;

$$H^2 = \frac{1}{(1+x^2)^4}. \quad (3)$$

The following additional conclusions were also obtained [2];

- 1- The mapping  $x$  to  $-x$  creates an anti-soliton and the two are stable (lifetime is infinite).
- 2- The lines of force are closed circles leading to a standing wave configuration with spherical symmetry.
- 3- All the lines of force are linked leading to a donut surface geometry.
- 4- The soliton descriptors are *independent of the medium properties*.
- 5- Energy, shape, rotational momentum and magnetic field at its center are all related and conserved for the Soliton.

The above results show that an EM soliton is indeed suitable for modeling an electron. It produces an electron that is; stable, spherically symmetric, satisfies Maxwell Equations for empty space (since no material constants are involved) while containing no hard core or anything moving at other than radiation at the speed of light. Further, it makes the electron appear to be a result of a spinning energy flux as suspected by many researchers for a long time [3,4]. This is a quote from [4] for example;

*“The detail studies on Dirac model by Schrodinger and others, show that the electron undergoes an internal oscillatory motion having dimension of the order of Compton wavelength, called the Zitterbewegung. From the Dirac equation of motion for a free electron, Schrodinger showed that even in linear motion the electron executes an oscillatory motion... He further concluded that the instantaneous velocity of a slowly moving electron is  $c$ ”.*

The last sentence is nearly impossible to comprehend without a trapped-wave model as that of a soliton. It might also be worth pointing that the equations representing the solitons have been found longtime before in other fields- in connection with the *Pythagorean boxes* for example. These are boxes with all sides being integers and also in their longest diagonal length [5,6]. This points to a fundamental nature of the soliton equations.

## 10 Soliton Structure Plots

The soliton equations (1) don't contain a time variable as they represent a standing wave solution. In principle, we should compare with the standard vector EM wave equation. We know that the magnetic field, electric field and the EM vector potential  $\mathbf{A}$ , all satisfy the same vector wave equation. The standing form of such equation can be provided by the so called *Helmholtz* form of the wave equation. This is given for magnetic vector potential  $\mathbf{A}$  by;

$$\nabla^2 \mathbf{A} = k \mathbf{A}, \quad \text{or in terms of the components;} \quad \nabla^2 A_i / A_i = \text{constant.} \quad (4a,b)$$

Now, equation(4b) is a wave equation that doesn't contain time and is ready to be used for comparing with the soliton equations (1). The plots of the development of the vector potential (1) with time (before reaching the steady state) is given in Figs(2a,b) for two short and long periods of time. Fig(3a) gives the first few circles of  $A_i$ , and Fig(3b)

gives three plots for the supposedly constant (for each component) ratios in (4) for the three components of  $A$ . Fig(3c) gives the magnitude  $|A|$  for random values inside the region of interest. Fig(4d) shows the decay of energy away from the center of the soliton. A ready to use algorithm for these plots is given below;

```
%Algorithm to generate Figs (3) ****
clear all;close all;
n=1e3;dt=1;x=1;y=1;z=1;X=[];Y=[];Z=[];
for kk=1:n; r2=x^2+y^2+z^2;
u0=(1/2)/(1+r2)^2; u=u0*(-y+x*z); v=u0*(x+y*z);
w=(1/2)*(2*z^2+1-r2);f2=u^2+v^2+w^2;f=sqrt(f2);
Ik=4*f2./(1+r2); %HelicityL=Intg(I.rot(I)d^3(x);He=rot(I)=4I2/(1+r^2).
x=x+dt*u;y=y+dt*v;z=z+dt*w;X(kk)=x;Y(kk)=y;Z(kk)=z;
I(kk)=Ik;end;'kk';Im=mean(I);
Figure (1);plot3(X,Y,Z,'r');grid on;title(['Helicity= ' num2str(Im)]);
```

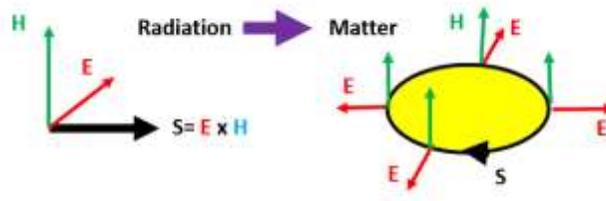
## 11 Conclusions

We postulated that space-time is best represented by radiation, and that EM solitons are what appears in a pair production process, thus giving the most intuitive way of representing the physics of transformations between radiation and matter. The soliton structure is formed from a self-trapped standing EM wave configuration satisfying all of what is known of the electron attributes. This construct is further capable of explaining the emergence of all the matter attributes of; mass, gravity, charge, spin and a magnetic dipole moment. We further concluded that all types of energies are only a result of absorbing more radiation that carries momentum- to be added to that of the particle momentum causing it to move. A particle acquires an additional rest mass instead of moving if the received radiation is in two opposite directions with net zero momentum. The equations for an EM soliton have been worked out in [4], and also found to be present in the structure of all integer Pythagorean boxes [1,2]. Gravity and static electricity inverse square forces existence is found to be seated in momentum conservation and the full form of gravity and EM forces are only the consequence of the inverse square forces being delayed due to the limited speed of propagation of forces- the speed of light in empty space as shown by the well known *retarded potential integral* and the Lienard-Wiechert equations. As Wheeler suspected, the missing positron anti-matter can be hidden inside the proton (in the many positronium atoms) and the reasons for the quantization of the various matter attributes also comes out naturally of the present construct. The universe looks fractal is due the laws of gravity and electricity being scalable- a consequence of momentum conservation.

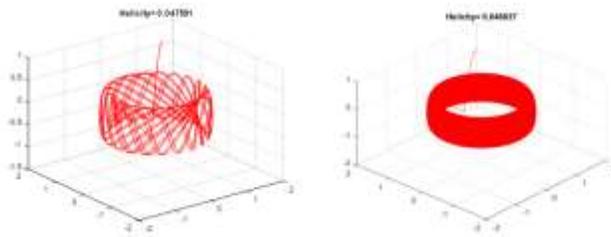
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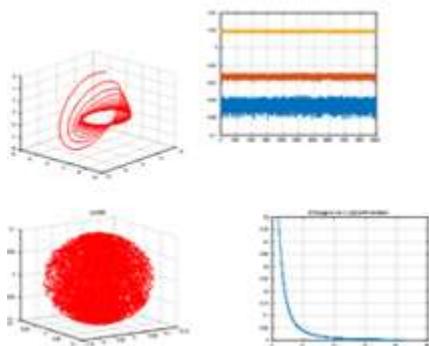
## Figures



**Fig 1.** Proposed radiation to matter transformation and the emergence of matter attributes.



**Figs 2 a,b.** EM Topological Solution.  
Time development of the vector potential  $A$



**Figs 3 a,b,c,d.** Left to right and top to bottom.  
Tests of the soliton behavior

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