The metron model. Towards a unified deterministic theory of fields and particles

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ABSTRACT

A summary is given of the principal concepts of a unified deterministic theory of fields and particles that have been developed in more detail in a previous comprehensive four-part paper (Hasselmann, 1996a,b, 1997a,b). The model is based on the Einstein vacuum equations, Ricci tensor $R_{LM} = 0$, in a higher-dimensional space. A space of at least eight dimensions is required to incorporate all other forces as well as gravity in Einstein's general relativistic formalism. It is hypothesized that the equations support soliton-type solutions ("metrons") that are localized in physical space and are periodic in extra ("harmonic") space and time. The solitons represent waves propagating in harmonic space that are locally trapped in physical space within a wave guide produced by a distortion of the background metric. The metric distortion, in turn, is generated by nonlinear interactions (radiation stresses) of the wave field. (The mutual interaction mechanism has been demonstrated for a simplified Lagrangian in Part 1 of the previous paper). In addition to electromagnetic and gravitational fields, the metron solutions carry periodic far fields that satisfy de Broglie's dispersion relation. These give rise to wave-like interference phenomena when particles interact with other matter, thereby resolving the wave-particle duality paradox. The metron solutions and all particle interactions on the microphysical scale (with the exception of the kaon system) satisfy strict time-reversal symmetry, an arrow of time arising only at the macrophysical level through the introduction of time-asymmetrical statistical assumptions. Thus Bell's theorem on the non-existence of deterministic (hidden variable) theories, which depends crucially on an arrow-of-time, is not applicable. Similarly, the periodic de

Broglie far fields of the particles do not lead to unstable radiative damping, the time-asymmetrical outgoing radiation condition being replaced by the time-symmetrical condition of zero net radiation.

Assuming suitable polarization properties of the metron solutions, it can be shown that the coupled field equations of the Maxwell-Dirac-Einstein system as well as the Lagrangian of the Standard Model can be derived to lowest interaction order from the Einstein vacuum equations. Moreover, since Einstein's vacuum equations contain no physical constants (apart from the introduction of units, namely the velocity of light and a similar scale for the harmonic dimensions, in the definition of the flat background metric), all physical properties of the elementary particles (mass, charge, spin) and all universal physical constants (Planck's constant, the gravitational constant, and the coupling constants of the electroweak and strong forces) must follow from the properties of the metron solutions. A preliminary inspection of the structure of the solutions suggests that the extremely small ratio of gravitational to electromagnetic forces can be explained as a higher-order nonlinearity of the gravitational forces within the interior metron core. The gauge symmetries of the Standard Model follow from geometrical symmetries of the metron solutions. Similarly, the parity violation of the weak interactions is attributed to a reflexion asymmetry of the metron solutions (in analogy to molecules with left- and right-rotational symmetry), rather than to a property of the basic Lagrangian. The metron model also yields further interaction fields not contained in the Standard Model, suggesting that the Standard Model represents only a first-order description of elementary particle interactions.

While the Einstein vacuum equations reproduce the basic structure of the fields and lowest-order interactions of quantum field theory, the particle content of the metron model has no correspondence in quantum field theory. This leads to an interesting interpretation of atomic spectra in the metron model. The basic atomic eigenmodes of quantum electrodynamics appear in the metron model as the scattered fields generated by the interaction of the orbiting electron with the atomic nucleus. For certain orbits, the eigenmodes are in resonance with the orbiting electron. In this case, the eigenmode and orbiting electron represent a stable self-supporting configuration. For circular orbits, the resonance condition is identical to the integer-action condition of the Bohr orbital model. Thus the metron interpretation of atomic spectra yields an interesting amalgam of quantum electrodynamics and the original Bohr model. However, it remains to be investigated whether higher-order computations of the metron model are able to reproduce atomic spectra to the same high degree of agreement with experiment as QED. On a more fundamental level, the basic questions of the existence, structure, stability and discreteness of the postulated metron solutions still need to be addressed. However, it is encouraging that, already on the present exploratory level, the basic properties of elementary particles and fields, including the origins of particle properties and the physical constants, can be explained within a unified classical picture based on a straightforward Kaluza-Klein extension to a higher dimensional space of the simplest vacuum form of Einstein's gravitational equations.

1 Unification and Beyond

Since the conception of quantum theory some seventy years ago, the development of physics has been beset by a two-fold dichotomy. Despite intensive efforts, attempts to unify quantum theory with the second basic pillar of modern physics, general relativity, have so far proven unsuccessful[1]. At the same time, the revolutionary innovation of quantum theory, the rejection of the concept of mathematically defined objects at the microphysical level, has divorced physics from its traditional objectivistic foundations that have continued to form the basis of advances in all other areas of science[2].

In the following I shall outline an "objectivistic" (sometimes termed "realistic") "metron" theory of fields and particles that I believe is able to resolve both dichotomies. The basic concept is that one can define physical objects, in the classical sense, that solve the wave-particle duality conflict of microphysics by exhibiting both corpuscular and wave-like phenomena. The objects represent soliton-type solutions of the Einstein vacuum equations in eight (or higher) dimensional space. The extension of Einstein's gravitational equations to a higher dimensional space is motivated, as in the original approach of Kaluza (1921) and Klein (1926), by the desire to include further forces in the framework of Einstein's elegant general relativistic theory of gravity. At least eight dimensions are needed to include all forces. The reduction of Einstein's equations to the vacuum form is an important further step that enables the properties of matter to be derived from the nonlinear structure of the soliton solutions, rather than postulating the existence of matter and inserting the relevant source terms into the field equations *a priori*. The soliton solutions (" metrons") are locally concentrated in physical three-dimensional space, thereby exhibiting corpuscular-like properties, but at the same time carry periodic far fields that produce wave-like interference phenomena. They are also periodic with respect to (or independent of) the extra-space coordinates. The metron model yields the Einstein gravitational equations with matter in physical spacetime, together with the basic field

[1]cf. Maiani and Ricci, 1996. Most of these approaches, such as the current string theories or the Ashtekar (1988) programme, have been based on attempts to quantify gravity, rather than to question the basic premises of quantum theory .

[2]The conceptual stagnation in the development of the foundations of physics may be constrasted, for example, with the spectacular advances made in microbiology by systematically developing models based on clearly defined objects, such as DNA molecules, messenger and transfer RNA molecules, vector viruses, etc.

equations and symmetries of quantum field theory (QFT), as summarized in the Standard Model of elementary particles.

The motivation for developing a unified theory of fields and particles that overcomes the conceptual paradoxes of the Copenhagen school is not only aesthetic. The development of a new view of physics necessarily yields new insights, leading to new questions with new answers. Thus I shall show that the metron model is able to derive or explain the origin of all fundamental particle properties that are introduced axiomatically in classical gravity and quantum field theory: mass and electric charge; the composition of the elementary particle spectrum; particle symmetries and symmetry breaking; the nature of physical forces, including the exceptional weakness of the gravitational force; and all physical constants. Since the Einstein vacuum equations contain no free constants (apart from the defining spatial scales introduced in the normalization of the background metric), all of these properties must necessarily follow from the nonlinear structure of the metron solutions.

Whether or not the metron theory will satisfy all these expectations remains to be investigated. In a first analysis (Hasselmann, 1996a,b, 1997a,b, referred to in the following as I - IV, respectively), it was shown that appropriate soliton-type solutions of the n-dimensional Einstein vacuum equations, if they exist, yield the standard Einstein gravitational equations in four-dimensional spacetime, including the energy-momentum source terms; the coupled field equations of the Maxwell-Dirac-Einstein system, including the elementary charge; atomic spectra; the ratio of gravitational to electromagnetic forces; and the basic structure and symmetries (with differences in detail) of the remaining coupled field equations of QFT, in accordance with the Standard Model. Soliton-type solutions of the posutulated dynamical structure were furthermore computed explicitly for a simplified scalar Lagrangian that captured the basic nonlinearities of the Einstein vacuum Lagrangian while suppressing its tensor complexities. However, numerical computations for the full Einstein system in n-dimensional space have still to be carried out. In the following summary, I shall outline the principal concepts of the metron model, without entering into the details of the mathematics presented in I - IV.

2 Is a unified deterministic theory of fields and particles feasible?

A program to develop a unified theory of fields and particles based on classical, objectivisic physics must face two basic objections:

1) As a method of categorizing and computing an enormous variety of phenomena – some, as in quantum electrodynamics, at very high accuracy – quantum theory has proven immensely successful. It appears intrinsically unlikely that a theory based on entirely different concepts will be able to reproduce the detailed results of standard quantum theory. The response to this objection is that the metron model yields the basic coupled field equations of QFT to lowest interaction order, and is thus able to reproduce the principal results of QFT. However, at higher order the metron model departs from standard QFT: the interaction terms of the Lagrangians differ beyond the lowest coupling order, and the metron model has no closed loop contributions, divergences or renormalization formalism. Thus, it remains to be seen to which level of accuracy the two theories are, in fact, equivalent. It is of interest in this context that Barut (1988) has claimed that classical tree-level computations of the hydrogen atom spectrum agree better with measurements than the computations of quantum electrodynamics.

Despite the close equivalence of the field content of the two theories, the metron picture is fundamentally different from that of standard quantum field theory. The metron model is characterized not only by the basic field equations, but also by the discrete corpuscular solutions of the field equations. Thus, discrete atomic spectra are represented in the metron model not only by the eigensolutions of the Schrödinger equation (or the corresponding relativistic Maxwell-Dirac equations), but also by the discrete orbits of the associated electrons that are resonantly coupled to the eigenmodes. The theory therefore effectively combines quantum electrodynamics with the original Bohr orbital model (see Section 5).

2) Apart from its practical success, quantum theory is also generally believed to be the only feasible approach to resolving the wave-particle duality paradoxes of microphysics. Although von Neumann's original "proof" that the duality paradoxes cannot be resolved within the framework of classical objectivistic physics has been demonstrated by Bohm (1952) and Bell (1964) to rest on invalid assumptions, Bell himself has provided an alternative, widely accepted proof. In his celebrated theorem on the Einstein-Podolsky-Rosen

experiment, Bell demonstrated that under general, apparently plausible conditions, it is not possible to explain the paradox of the EPR experiment in terms of a classical hidden-variable theory. However, Bell also pointed out that his proof rested critically on the assumption of causality, in the sense of the existence of an arrow of time. As discussed below, the metron model is based on strict time-reversal symmetry on the microphysical level, so that Bell's theorem does not apply. An interpretation of the EPR experiment from the viewpoint of time-reversal symmetry is given in III.

Time-reversal symmetry on the microphysical level is also the reason that the metron solutions are able to support stable periodic far fields. In contrast to the standard view that such solutions must decay through radiation to infinity, the time-asymmetrical boundary condition of outgoing radiation is replaced in the metron model by the time-symmetrical condition of zero net radiation (equal and opposite ingoing and outgoing radiation). This permits stable standing-wave solutions. The outgoing-radiation condition arises only later at the macrophysical level through the introduction of time-asymmetrical statistical assumptions (see discussion in Einstein, 1909, Wheeler and Feynman, 1949, III and also Gutzwiller, 1990).

3 Wave-particle duality

Quantum theory was invented to resolve the wave-particle paradox. The difference between the quantum-theoretical and metron approach to this problem is best illustrated by an experiment in which a uniform stream of particles of given momentum is observed to exhibit wave-like interference phenomena on interacting with an object. Instead of the traditional single- or double-slit experiment, I consider the case of Bragg scattering at a periodic lattice, as this is more amenable to elementary analysis.

If the particle stream is sufficiently weak, it is possible to measure individual particles immediately after they leave the particle source, and again after they have been Bragg scattered by the lattice, when they impinge, for example, on a particular counter of a particle counter array located behind the lattice. In the naive classical view, it is clear that one is measuring individual particles, with reasonably well defined initial and final positions and momenta[3]. However, in apparent conflict with this result, the statistical dis-

[3]That these underly the Heisenberg uncertainty relation is not relevant for the present discussion

tribution of particle counts is found to correspond to the interference pattern of a periodic wave incident on the lattice.

The quantum theoretical response to this finding is that one is faced with an insurmountable contradiction that can be circumvented only by rejecting both premises that one is observing either a particle or a wave. One introduces instead a general formalism for predicting the statistical outcome of microphysical experiments without defining what microphysical objects actually are. In fact, it is stated that physical objects in the classical sense do not exist at the microphysical level. In contrast to the prevalent Copenhagen view, the metron concept is based on the alternative, rather obvious conclusion that one is indeed observing real, discrete particles, but that the interactions of the particles with other objects exhibit wave-like interference phenomena[4].

To produce interference phenomena, the particles must carry periodic far fields. In the usual classical picture, this would lead to radiative damping, and would thus not be acceptable for a stable particle. However, as mentioned above, at the microphysical level of fundamental particles, radiative damping is excluded in the metron model as a time-asymmetrical process. Radiative damping is explained within the framework of time-symmetrical elementary interactions as a macrophysical phenomenon involving irreversible interactions of an accelerated test particle with a non-time-symmetrical statistical ensemble of distant particles (Wheeler and Feynman, 1948, III, see also Einstein, 1909).

In order to reproduce the interference characteristics of de Broglie waves, the wavenumbers of the particles' periodic far fields must satisfy de Broglie's relation[5]

$$k_\mu = p_\mu/\hbar = m u_\mu/\hbar, \tag{1}$$

where p_μ is the four-momentum, u_μ the velocity and m the rest mass of the particle. In the particle restframe, the field is periodic in time with (angular) frequency

$$\omega = mc^2/\hbar, \tag{2}$$

[4]This is reminiscent of another Copenhagen school of thought, expounded by Hans Christian Anderson in his tale of the emperor's new clothes.

[5]De Broglie (1956) and Bohm (1952) have similarly proposed a theory of real particles and de Broglie waves. However, in contrast to the de Broglie-Bohm pilot wave model, the de Broglie fields in the present case are not regarded as separate entities guiding the particles, but rather as integral components of the particles' fields. The relation between the de Broglie-Bohm theory and the metron model will be discussed in a separate paper.

and has infinite wavelength (in the following natural units will be used, with $c = \hbar = 1$).

The interaction of the periodic far field of the particle (denoted in the following simply as the particle's de Broglie field) with the periodic lattice generates a set of scattered waves with wavenumbers $k_\mu^{(s)}$ given by the Bragg relation

$$k_\mu^{(s)} = k_\mu^{(i)} + k_\mu^{(l)}, \qquad (3)$$

where $k_\mu^{(i)}$ is the wavenumber of the incident particle and $k_\mu^{(l)}$ is one of the (not necessarily fundamental) periodicity wavenumbers of the lattice. In order to be able to propagate, the scattered waves must satisy the de Broglie free-wave dispersion relation (see below)

$$k_\mu^{(s)} k^{(s)\mu} = -\omega^2, \qquad (4)$$

where the background spacetime metric is defined as $\eta_{\nu\mu} = \mathrm{diag}(1, 1, 1, -1)$.

The relations (3) and (4) are identical to the usual scattering computations of quantum theory, which determine the resonant Bragg directions of the scattered particle beams. However, in the present deterministic particle picture, the scattered field cannot be simply identified with the particle beam, and one must ask further: how does the scattered Bragg field affect the individual particle trajectories?

Consider a particle that is deflected by the lattice into a scattered velocity $u_\lambda^{(s)}$. In the particle restframe, it will experience the scattered de Broglie field with the "frequency of encounter"

$$\omega^{(e)} = -k_\lambda^{(s)} u^{(s)\lambda}. \qquad (5)$$

If $\omega^{(e)}$ differs from the intrinsic particle frequency ω associated with its de Broglie wave, the interaction of the particle with the periodic scattered wave will average to zero: the scattered field has no impact on the particle trajectory. However, if $\omega^e = \omega$, the scattered field is in resonance with the intrinsic periodicity of the particle, and the quadratic interaction of the scattered field with the particle's intrinsic de Broglie field yields a mean force. It can be readily verified (III) that this second particle resonance condition requires a scattered particle velocity in the direction of the Bragg scattered wave,

$$u_\lambda^{(s)} = \omega^{-1} k_\lambda^{(s)}. \qquad (6)$$

Expressed in terms of the interaction Lagrangian of the scattered particle, the particle resonance with its scattered wave produces δ-function-type canyons in the potential energy, which effectively trap the particles in the preferred Bragg scattering directions. Thus the deterministic particle picture yields qualitatively similar results to the wave scattering computations of quantum theory: the scattered particle beams are concentrated in the discrete resonant Bragg scattering directions. A more detailed presentation of the trapping mechanism is given in III.

This simple example was described in some detail as it illustrates an important feature of the metron model: the model contains essentially the same field content as standard quantum field theory, but goes beyond QFT in providing also predictions for the trajectories of objectively existing discrete particles. The metron computations of the field interactions follow closely the quantum theoretical analysis based on resonant wave-wave interactions[6], while the computations of the particle trajectories require the consideration of further wave-particle interactions. In the present case, the dominant wave-particle interactions were determined by a second resonance condition. A similar wave-particle resonant-interaction condition is found to explain the origin of discrete electron orbits in the metron model of atomic spectra (Section 5). A more detailed discussion of the relation between the metron model and the standard QFT picture of elementary particles and fields, including a discussion of the Heisenberg uncertainty principle[7], boson-fermion statistics[8] and other fundamental features of QFT, is given in I.

4 Basic equations and structure of the metron model

Having recognized that the wave-particle duality paradox can be overcome if one accepts the notion that particles carry periodic de Broglie far fields, how can one introduce particles with this property? One approach could

[6]The resonance conditions express the conservation of four-momentum. A similar formalism can be applied also to resonant wave-wave interactions between geophysical wave fields, see Hasselmann (1966).

[7]Although the position and momentum of a particle can be simultaneously defined in principle in the metron picture, Heisenberg's uncertainty relation follows in practice from the impossibility of reducing an initial uncertainty $\Delta x.\Delta p > \hbar$ in the position and momentum of a particle through a measurement process involving interactions with another system that underlies a similar uncertainty – see Bohm (1952).

[8]See also next section

be to simply postulate the existence of discrete particles with the required properties, together with the fields needed to describe their interactions. This would be analogous to the axiomatic introduction of the various particle fields and their interactions in QFT. However, if one regards this as unsatisfactory, one must explain the existence and properties of particles as the solutions of some set of (nonlinear) field equations. Assuming that the ultimate goal is to develop a unified theory, the equations must contain as a minimum both Einstein's gravitational equations and Maxwell's equations. It has been shown by Kaluza (1921) and Klein (1926) that both systems of equations can be derived from Einstein's equations in a higher dimensional space. So why not try Einstein's equations in some n-dimensional space?

If one wishes to pursue further the goal of explaining the origin of mass, charge and the coupling constants of the weak and strong interactions, the source terms in the n-dimensional Einstein equations, in which these constants would appear, must be dropped. Thus I take as the basic equations of the metron model simply the Einstein vacuum equations

$$R_{LM} = 0 \tag{7}$$

in some n-dimensional space, where g_{LM} denotes the metric, R_{LM} the Ricci curvature tensor,

$$R_{LM} := \partial_M \Gamma^N_{LN} - \partial_N \Gamma^N_{LM} + P_{LM}, \tag{8}$$

$$P_{LM} := \Gamma^N_{LO}\,\Gamma^O_{MN} - \Gamma^N_{LM}\,\Gamma^O_{NO} \tag{9}$$

and the connection (Christoffel symbol) is given by

$$\Gamma^L_{MN} := \frac{1}{2}\, g^{LO}\, \left[\partial_M g_{ON} + \partial_N g_{OM} - \partial_O g_{MN}\right]. \tag{10}$$

I assume that soliton-type solutions of these equations that can be identified with discrete particles exist. Solitons have been extensively studied as solutions of the nonlinear equations of fluid dynamics. They normally represent a balance between linear dispersion, which tends to smooth out disturbances, and nonlinearities, which tend to concentrate disturbances (often towards a discontinuous shock). Solutions are normally found only in two dimensions, since in three dimensions, linear geometrical dispersion dominates over the nonlinearities.

The postulated metron solutions of the Einstein vacuum equations are soliton solutions of a basically different nature. They are comprised of a nonlinear superposition of a number of "partons". Each parton is localized in three-dimensional physical space and periodic with respect to time and extra-space (termed "harmonic space" in the following). The periodic wave fields propagate in a mean metric field that is distorted in three-dimensional space and thereby acts as a wave-guide: the wave phase velocities are reduced within the central core region of the particle, resulting in the total reflection of the waves near the edge of the particle core. The distortion of the metric, in turn, is produced by the nonlinear (to lowest order, quadratic "radiation stress" or "current") self- and cross-interactions of the wave field components. Since the wave amplitudes are largest within the metron core, this is also the region of the largest metric distortions. Thus the metron solutions represent a mutually supporting coupled trapped-mode/wave-guide system (Figure 1). Similar mutually sustained trapping interactions between waves and the medium in which they propagate have been studied in various geophysical applications (e.g. Garrett, 1976, Haines and Malanotte-Rizzoli, 1991). The existence of soliton-type solutions based on this trapped-mode/wave-guide interaction mechanism has been demonstrated in the present context in I for a simple scalar Lagrangian obtained by projecting the Einstein tensor equations onto a few modes. Computations of metron solutions of the full system of Einstein vacuum equations are currently in progress.

Since the individual parton components of the metron solutions are periodic in harmonic space with a small periodicity scale $1/k$ (the wavenumber k is found to be proportional to the coupling strength, see below), the n-dimensional space is compactified in the metron solution into a thin (n-4)-dimensional sheet with non-trivial structure only in the remaining 4-dimensional physical spacetime.

In the following I assume that trapped-mode soliton-type solutions of these equations exist. Thus the metric can be represented as a superposition of parton fields (p) that are periodic in harmonic space and time and localized in physical space,

$$g_{LM} = \eta_{LM} + \sum_p g_{LM}^{(p)} \tag{11}$$

where g_{LM} is the total metric field, the background metric is given by $\eta_{LM} = \text{diag}\,(1, 1, 1, -1, 1, \ldots, 1)$[9], and the periodic parton components

$$g_{LM}^{(p)} := \hat{g}_{LM}^{(p)}(x) \exp(iS^p) + \text{compl. conj.}, \tag{12}$$

[9]In II and IV, a non-Euclidean background harmonic metric, $\eta_{LM} = \text{diag}\,(1, 1, 1, -1, \pm 1, \ldots, \pm 1)$, is also considered.

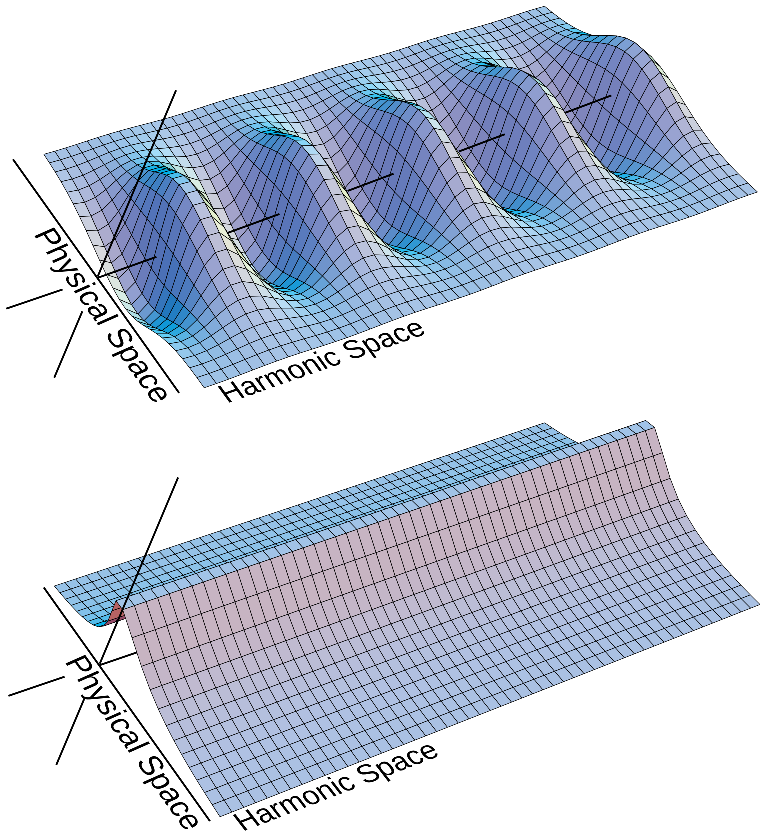

Figure 1: Schematic diagram of trapped-mode (upper panel) and wave-guide (lower panel) components of a metron particle. Plotted in the lower panel is the inverse of the phase speed; the reduced phase speed in the core region represents a wave-guide that traps the wave through total reflection near the edge of the core region (from I).

have phase functions

$$S^p := k_A^{(p)} x^A \tag{13}$$

with constant harmonic (extra-space) wavenumber vectors $k_A^{(p)}$ and amplitudes $\hat{g}_{LM}^{(p)}(x)$ that are functions of physical spacetime x only. In the parton restframe, the amplitudes are localized in physical space $\mathbf{x}$ and periodic in

space	components	vector
full n-dimensional space	x^L	$X = (x^1, x^2, \cdots, x^n)$
three-dimensional physical space	x^i	$\mathbf{x} = (x^1, x^2, x^3)$
four-dimensional physical spacetime	x^λ	$x = (x^1, x^2, x^3, x^4)$
$(n-4)$-dimensional harmonic space	x^A	$\mathrm{x} = (x^5, x^6, \cdots, x^n)$

Table 1: Index and coordinate notation

time $t = x^4$,

$$\hat{g}^{(p)}_{LM}(x) = \tilde{g}^{(p)}_{LM}(\mathbf{x}) \exp\left(-i\omega^{(p)} t\right), \tag{14}$$

where the frequency $\omega^{(p)} = -k_4^{(p)}$ is identified with the parton mass. There exist also massless partons with $\omega^{(p)} = 0$. The mean "wave-guide" metric-field component is included in the representation (11) as a component with zero frequency and harmonic wavenumber.

The index and coordinate notation used here and in the following is defined in Table 1. Non-tensor indices, which are excluded from the summation convention, are placed in parentheses.

The parton components interact at various orders of nonlinearity and consist generally of the fundamental and higher-harmonic components of a basis set of partons (normally fermions, for example, the three quarks of the proton/neutron system).

The representation (11) of the full metric field g_{LM} as a sum of perturbations $g^{(p)}_{LM}$ superimposed on the flat-space background metric η_{LM} implies that interactions between the perturbations can be represented as a nonlinear series expansion (which need not be restricted to weak interactions, however). Furthermore, through the assumption of a flat background metric we disregard here the problem of the imbedding of the local background metric in a more general curved space on cosmological scales.

The coordinate system can be chosen such that all parton components satisfy the gauge condition

$$\partial^L h^{(p)}_{LM} = 0, \tag{15}$$

where

$$h^{(p)}_{LM} := g^{(p)}_{LM} - \frac{1}{2}\eta_{LM}\, g^{(p)N}_{N} \tag{16}$$

is the trace-reversed representation of the metric perturbation.

In the linearized approximation, the gravitational equations reduce in this case for each parton component to the n-dimensional wave equation

$$\partial_N \partial^N g^{(p)}_{LM} = 0, \tag{17}$$

which yields for the parton amplitudes the Klein-Gordon equation

$$\left(\Box - \hat{\omega}^{(p)2}\right) \hat{g}^{(p)}_{LM} = 0, \tag{18}$$

where the "harmonic" frequency $\hat{\omega}^{(p)}$ is defined as[10]

$$\hat{\omega}^{(p)} := \left(k^{(p)}_A k^A_{(p)}\right)^{1/2}. \tag{19}$$

The field equations of QFT and classical gravity, including the source terms, are obtained from Einstein's vacuum equations in n-dimensional space by assigning each parton component $g^{(p)}_{LM}$ to one of the basic fields $\phi^{(a)}$ of QFT or classical gravity. The relation between the components of the n-dimensional metric and the standard fields of QFT and gravity is established through a set of polarization matrices $P^{(p)}_{(a)LM}$,

$$\hat{g}^{(p)}_{LM} = \sum_{(a)} P^{(p)}_{(a)LM} \phi^{(a)}. \tag{20}$$

The assignment of the different QFT and classical gravity fields to the various components of the n-dimensional metric is summarized in table 2. Fermions (and the Higgs field) are assigned to harmonic-sector metric components, while bosons are represented by metric components with mixed spacetime-harmonic indices. The basic trapped-mode fields of the metron solutions are comprised of fermions, the bosons being auxiliary fields generated by quadratic (difference) interactions between fermions. The corpuscular properties of matter (in particular, the particle mass) are determined by the fermion fields. Bosons (for example, photons) are not regarded as particles in the metron model, but as classical fields. They derive their corpuscular-like properties from the transitions between discrete particle states that they mediate (Lorentz, 1904). The Fermi-Dirac and Einstein-Bose statistics of fermions and bosons (in particular, the Pauli exclusion principle) follows in the metron model simply from the observation that it is not possible for two existing particles (fermions) to be at the same position at the same time,

	spacetime indices	harmonic indices
spacetime indices	gravity $g_{\lambda\mu}$	bosons $\hat{g}^{(b)}_{\lambda A} = B_\lambda a^{(b)}_A$
harmonic indices	bosons $\hat{g}^{(b)}_{A\lambda} = a^{(b)}_A B_\lambda$	fermions $\hat{g}^{(f)}_{AB} = P^{(f)a}_{AB} \psi_a$ scalars $\hat{g}^{(s)}_{AB} = P^{(s)}_{AB} \varphi$

Table 2: Associated metric tensors and polarization relations for gravitational fields $g_{\lambda\mu}$, vector bosons B_λ, fermions ψ_a and scalar fields φ ($a^{(b)}_A$ = const = bosonic polarization factor). Metric fields represent deviations from the flat-space background metric η_{LM} and represent, in general, the complex amplitudes of periodic fields, cf. eqs. (12), (20).

while it is quite feasible to superimpose the associated boson fields of different particles.

For finite-mass fields, which are periodic in harmonic space, the amplitudes $\phi^{(a)}$ and polarization matrices $P^{(p)}_{(a)LM}$ are complex. This enables the representation of complex fields such as Dirac four-spinors in terms of the tensor components of the real n-dimensional metric[11].

As pointed out, since the Einstein vacuum equations (7) contain no physical constants beyond the scale normalization, all particle constants and the universal physical constants that describe their interactions must be determined in the metron model by the metron solutions. In addition to the normal invariance with respect to coordinate transformations (diffeomorphisms), the Einstein vacuum equations are invariant under an arbitrary common scale change in all coordinates (without otherwise modifying the metric field). One can therefore arbitrarily assign a unit to one of the fundamental harmonic space wavenumbers of the metron solutions. The values of all other wavenumbers with respect to this reference wavenumber, as well as

[10]For linear fields, the harmonic and de Broglie frequencies are the same, $\hat{\omega}^{(p)} = \omega^{(p)}$, but in the general nonlinear case, $\hat{\omega}^{(p)} \neq \omega^{(p)}$.

[11]It may appear surprising at first sight that half-integer spin fields can be represented in terms of an integer-spin metric field. However, it should be noted that the polarization relations for Dirac fields apply to the harmonic rather than the spacetime sector of the n-dimensional metric, see Table 2 and the discussion in II.

the magnitudes and polarization structures of the metric field components, are then determined by the properties of the metron solutions.

In discussing the relation of the metron model to QFT and classical gravity, one must consider both the field and particle content of the metron model. The field content can be directly related to QFT and to the field equations of classical gravity (with the exclusion of the energy-momentum source terms). However, the metron particle picture has no direct counterpart in QFT and can therefore be related only to the classical picture of interacting point particles (see, for example, Wheeler and Feyman, 1949, for the case of electromagnetic interactions). It can be shown that the particle picture of the metron model reproduces the point-particle source terms of both Maxwell's equations and classical gravity, at the same time determining the relevant particle properties and physical coupling constants. I discuss first field-field interactions and subsequently field-particle (or, equivalently, particle-particle) interactions.

4.1 Field interactions

To derive the field equations of QFT and classical gravity from the metron field equations, one simply substitutes the postulated polarization relations (20) into the Einstein vacuum equations and separates the resulting linear and nonlinear terms with respect to the basic parton fields. It is rather surprising that one does indeed recover in this manner all the basic field equations, with the correct lowest-order interaction terms, of QFT and classical gravity, including not only the Maxwell-Dirac-Einstein system (II), but also the weak and strong interactions, with associated fermions, bosons, and even the Higgs field, as summarized in the Standard Model (although with minor differences in detail, see IV).

The relations between the various components of the Ricci tensor and the field equations for the Maxwell-Dirac-Einstein system are indicated in Table 3. The field equations of classical gravity (excluding the source terms, that are discussed in the next subsection) follow trivially by identifying the physical spacetime sector $g_{\lambda\mu}$ of the n-dimensional metric with the classical gravitational metric. The harmonic-space subsegment g_{AB} of the n-dimensional metric is identified with fermion fields (in the general case of the Standard Model, also the Higgs field). To recover the four-spinor properties of the fermion fields, the dimension of full space must be at least eight. A particularly simple form of the spinor polarization matrices follows for

	4d-spacetime	harmonic sector
4d-spacetime	4d-gravity: $R_{\lambda\mu} = 0$ $\rightarrow \Box\, h_{\lambda\mu} = -2\, G\, T_{\lambda\mu}$	Maxwell: $R_{5\lambda} = 0$ $\rightarrow \Box\, A_\lambda = q(\psi\gamma_\lambda\psi)$
harmonic sector	Maxwell: $R_{\lambda 5} = 0$ $\rightarrow \Box\, A_\lambda = q(\psi\gamma_\lambda\psi)$	Dirac: $R_{AB} = 0$ $\rightarrow \left(\gamma^\lambda \partial_\lambda + \omega\right)\psi = iqA_\lambda\psi$

Table 3: Relation between the Ricci components R_{LM} of the n-dimensional metric and the field equations of the Maxwell-Dirac-Einstein system. $A_\lambda, q, \psi, h_{\lambda\mu}, G$ and $T_{\lambda\mu}$ denote the electromagnetic potential, charge, Dirac 4-spinor, trace-reversed 4-dimensional gravitational field, gravitational constant and energy-momentum tensor, respectively (see Section 6 for extension to the Standard Model).

a four-dimensional harmonic sub-space with Euclidean background metric, $\eta_{AB} = \text{diag}\,(1, 1, 1, 1)$, but other models are conceivable.

The electromagnetic field is represented by the metric component $g_{5\lambda}$. In the general case of the Standard Model, bosons are represented by mixed-index metric fields $g_{\lambda A}$. They are generated by quadratic difference interactions between fermions. The quadratic sum interactions and higher order interactions have no counterpart in the Standard Model, which appears therefore from the metron viewpoint only as an approximation.

Linear terms are shown on the left hand sides of Table 3; they are obtained by direct substitution of the polarization forms (20) (see also table 2) into the linearized n-dimensional vacuum gravitational equations and involve no cross-coupling with other sectors of the gravitational metric. In contrast, the nonlinear source terms on the right-hand sides arise through cross-coupling to other sectors. The matter source term (the energy-momentum tensor $T_{\lambda\mu}$) of the 4-dimensional gravitational equations is determined by higher-order interactions than the source term (the electromagnetic current) of the Maxwell equations (see discussion in the next sub-section).

The QFT coupling constants follow from the polarization matrices and are proportional generally to the wavenumbers of the interacting parton components. The gauge symmetries of the Standard Model are explained as geometrical symmetries of the metron solutions. Thus the parity violation of the weak interactions, for example, is attributed to a geometrical property of the metron solutions themselves (in analogy with the existence of molecules with left- or right-rotational symmetry) rather than to a reflectional asymmetry of the basic Lagrangian.

4.2 Field-particle interactions

For QFT, it is sufficient to specify the coupling between the basic fields of the theory. There exists then a formalism for computing (in principle) the statistical outcome of the interactions between particles of any given configuration. In the metron model, however, the field interactions are only part of the picture. All fields are rooted in real discrete particles, and – as discussed in the example of Bragg scattering – their interactions are of interest mainly through their effect on the trajectories (or stabilities) of the associated particles. Since the concept of an objective, localized particle is foreign to QFT, the metron picture of interacting particles must be related to the classical picture of interacting point particles. This is restricted, however, to the gravitational and electromagnetic distant-interaction fields, for which the interacting particles can indeed be treated as point particles characterized by a mass and charge, with a universal gravitational coupling constant G (the electromagnetic coupling constant is absorbed in the definition of charge).

The classical gravitational and electromagnetic coupling between a set of point particles (i) can be expressed (II) by the action

$$W_{cl} := W_g + W_A + W_{pg} + W_{pA}, \tag{21}$$

consisting of the sum of two field action integrals

$$W_g := -\frac{1}{4G} \int \left\{ \partial_\lambda g^{\mu\nu} \partial^\lambda g_{\mu\nu} - \frac{1}{2} \partial_\lambda g^\mu_\mu \partial^\lambda g^\nu_\nu \right\} d^4x \tag{22}$$

$$W_A := -\frac{1}{2} \int F_{\lambda\mu} F^{\lambda\mu} \, d^4x \tag{23}$$

and two particle-path action integrals

$$W_{pg} := -2 \sum_i \int_{T_{(i)}} m_{(i)} \left\{ -g_{\lambda\mu} u^\lambda_{(i)} \, u^\mu_{(i)} \right\}^{1/2} ds \tag{24}$$

$$W_{pA} := 2 \sum_i \int_{T_{(i)}} q_{(i)} A_\lambda \, u^\lambda_{(i)} \, ds, \tag{25}$$

where

$$F_{\lambda\mu} = \partial_\lambda A_\mu - \partial_\mu A_\lambda \tag{26}$$

is the electromagnetic field, A_λ the electromagnetic potential, and $m_{(i)}, q_{(i)}, T_{(i)}$ the mass, electromagnetic charge and trajectory, respectively, of particle (i).

Variation of the path integrals with respect to the particle path $T_{(i)}$ yields the particle equations of motion (dropping the particle index (i))[12]

$$\frac{du^\lambda}{ds} + \Gamma^\lambda_{\mu\nu} u^\mu u^\nu = \frac{q}{m} F^\lambda_\mu u^\mu, \tag{27}$$

while variation of the action integrals with respect to the gravitational field $g_{\lambda\mu}$ and electromagnetic potential A^λ yields the field equations.

For the gravitational field one obtains (linearizing the left hand side, since we are concerned here only with the interactions with the source terms)

$$\Box\, h_{\lambda\mu} = -2\, G\, T_{\lambda\mu}, \tag{28}$$

where $h_{\lambda\mu} = g'_{\lambda\mu} - \frac{1}{2}\,\eta_{\lambda\mu} g'^{\nu}_{\nu}$ is the trace-reversed representation of the perturbation $g'_{\lambda\mu} = g_{\lambda\mu} - \eta_{\lambda\mu}$ of the 4-dimensional gravitational field about the reference background metric $\eta_{\lambda\mu}$, and the source term is given by the energy-momentum tensor

$$T_{\lambda\mu} := \sum_i m_{(i)} \int_{T_{(i)}} ds\, u_\lambda\, u_\mu \delta^{(4)}(x - \xi(s)). \tag{29}$$

The corresponding electromagnetic field equations are

$$\Box\, A^\lambda = j^\lambda, \tag{30}$$

where the source term is given by the electric current

$$j^\lambda := \sum_i \int_{T_{(i)}} ds\, q^{(i)} u^\lambda \delta^{(4)}(x - \xi(s)). \tag{31}$$

How can one recover these classical field-particle interaction relations from the metron model? The starting point is the n-dimensional gravitational action (II)

$$W_n := \int |g_n|^{1/2}\, R\, d^n X, \tag{32}$$

[12] The following representation of particle interactions in terms of mediating fields can be formulated alternatively as direct particle-particle interactions by expressing the fields as Green-function integrals over the paths of the particles that generate the fields, cf. Wheeler and Feynman (1949).

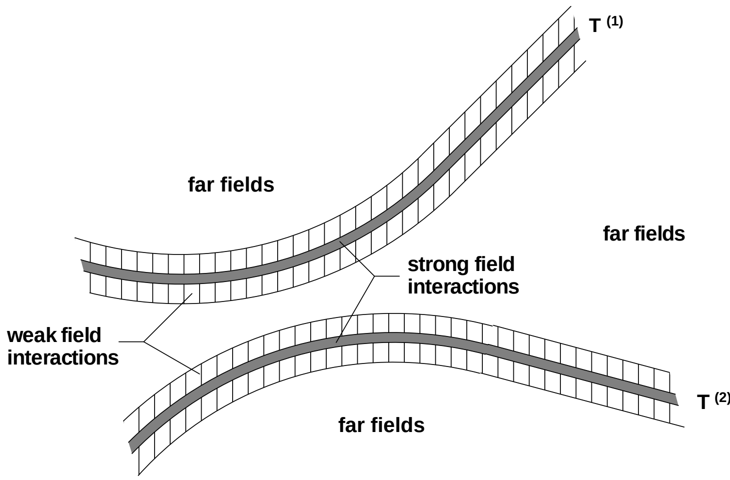

Figure 2: Metron paths, indicating the core regions of strong field interactions, the regions of weak field interactions and the linear far-field regions, that together determine the distant interactions between quasi-point particles.

where $R := R^L_L$ is the scalar curvature and $|g_n|$ the determinant of the metric. Since all fields are assumed to be periodic in or independent of harmonic space, the integral over harmonic space in (32) yields only a normalization factor and can be ignored. Thus the scalar curvature can be regarded as an harmonic-space average, and the integral in (32) restricted to physical spacetime.

By distinguishing between the near- and far-field regions of the integral, it can be decomposed into a spacetime integral and particle-path integrals, in accordance with the separate spacetime and path-integral components of the classical action expression (21). Formally, the physical spacetime integral is subdivided into near-field spacetime tubes encompassing the metron particle trajectories and the remaining far-field region (Fig.2). The particle tubes consist of an inner core of strong interactions that determine the structure of the trapped wave-mode/wave-guide metron solution, and an outer mantle in which the interactions (mainly "electroweak") are sufficiently weak to be treated as perturbations. In the far-field regions outside the trajectory tubes, the field interactions are neglible.

Substitution of the metron polarization relations (20) for the classical gravitational and electromagnetic fields into the gravitational action (32) yields in the far-field region the classical action expressions W_g (eq.(22)) and W_A (eq.(23)), while the action integrals over the particle trajectory tubes yield the classical path integral action expressions W_{pg} (eq.(24)) and W_{pA} (eq.(25)). To reduce the spacetime action integrals over the metron particle-trajectory tubes to path integrals, the n-dimensional scalar curvature must be integrated across the tube cross-sections. The cross-section averages yield the particle mass m, charge q and the gravitational coupling constant G as functions of the metron solution within the nonlinear near-field region.

Variation of the n-dimensional gravitational action also yields generally the Einstein-Maxwell-Dirac interaction equations in the outer mantle region of weak interactions and the complete system of interacting field equations in (approximate) accordance with the Standard Model within the metron core – as discussed already in the previous subsection. However, the focus here is not on the form of the field interactions or the structure of the metron solutions within the nonlinear tube region, but rather the integrated net coupling of the fields in the nonlinear tube region with the far fields of other particles. It is rather surprising that one does indeed recover from the metron model the detailed structure of the complete set of action integrals (22) - (25) that describe the classical gravitational and electromagnetic distant interactions between quasi-point particles - at the same time determining also the basic particle and coupling constants.

The gravitational constant G is of special interest. In contrast to the electromagnetic coupling, which is determined by the lowest-order interactions of the electromagnetic far field of particle (i) with the electromagnetic fields of particle (j) in the weak-field-interaction (mantle) region of particle (j), the gravitational coupling is found to vanish to this lowest interaction order. It is determined by higher-order interactions within the metron core. This explains the extreme weakness of the gravitational forces (and also the fact that the gravitational coupling appears only with one sign, i.e. that gravitational forces, in contrast to electromagnetic forces, are always attractive).

The particle mass appears in the metron formalism through the time derivative terms of the Ricci tensor. These yield expressions proportional to the metron frequency, which must be translated into the metron mass via Planck's constant (eq. (2)). Thus in the process of reproducing the classical distant-interaction relations for point particles, the metron model yields not only the particle mass, electric charge and the ratio of the gravitational to electromagnetic coupling, but also Planck's constant.

If this appears rather magical, it must be recalled that, since the Einstein vacuum equations contain no universal constants, all physical constants derived from the metron model must necessarily follow from the internal structure of the metron solutions, which contain only one free scale parameter, a reference wavenumber. Nevertheless, at the level of analysis outlined here, I have shown only that the existence of general trapped-mode metron solutions is plausible (I) and have otherwise simply postulated the structure of the polarization relations (20) required to reproduce the linearized field equations of classical gravity and QFT. The main result of the analysis summarized in Sections 4.1, 4.2 is that, under this premise, one recovers from the n-dimensional Einstein vacuum equations not only the linear field equations, but also the basic structure of the interactions between these fields. But there remains still the basic challenge of computing the metron solutions themselves and demonstrating that stable coupled wave-mode/wave-guide solutions with the assumed polarization relations do indeed exist.

5 Atomic spectra

A critical test of the metron model is whether it is able to match the impressive performance of quantum electrodynamics (QED) in the accurate computation of atomic spectra. However, before addressing this problem, one must consider first the more fundamental quesion: is it conceivable that a model based on the concept of real discrete particles is able to explain atomic spectra, which are treated in quantum theory as a pure eigenmode phenomenon? The answer lies again in the dual nature of the metron model, which comprises both field and particle elements. The field content reproduces the nonlinear wave dynamics of quantum field theory to lowest interaction order. Thus the spinor and electromagnetic components of the n-dimensional metric, defined by the polarization relations (20)[13], yield the coupled field equations of the Maxwell-Dirac system to lowest interaction order (II). The particle content is an additional feature that complements but does not alter the wave picture.

For the special case of a Dirac field ψ interacting with the prescribed electromagnetic field A_λ of an atomic nucleus, the field ψ is determined in QED by the Schrödinger equation, or in the general relativistic case, the

[13] The specific forms are given in II.

Dirac equation

$$D(\psi) := \left\{ \gamma^\lambda \left(\partial_\lambda - ieA_\lambda \right) + \omega \right\} \psi = 0. \tag{33}$$

This yields a discrete set of trapped eigenmodes ψ_m with eigenfrequencies ω_m, together with a continuum of free modes. In the metron model, in which there exists a real orbiting electron particle, one is concerned with three fields (Fig.3): the de Broglie field of the orbiting electron, the electromagnetic field of the atomic nucleus and the scattered de Broglie field generated by the interaction of the de Broglie field of the electron with the nucleus. The Dirac field ψ in (33) corresponds to the scattered de Broglie field. However, in addition to the terms representing the propagation of the scattered de Broglie field and its interaction with the electromagnetic field, which are identical to the corresponding terms of the Dirac equation (33) of QED, the metron model contains also a forcing term F representing the generation of the scattered field by the orbiting electron. Thus eq.(33) is replaced in the metron case by

$$D(\psi) = F \tag{34}$$

The forcing function F is periodic with approximately the basic de Broglie frequency of the orbiting electron, but contains a small frequency modulation imposed by the electron's orbital motion. If the resulting forcing frequency is equal to an eigenfrequency ω_m of one of the atomic eigenmodes, the eigenmode is forced in resonance and, in the absence of further interactions, would grow linearly with time. However, the eigenmode acts back, again in resonance, on the orbiting electron (Fig.3). The net effect of the simultaneous resonant interactions is that the orbiting electron is trapped in discrete orbits that are in resonance with the eigenmodes of eq.(33). Under these resonant trapping conditions, the resonant coupling generates a mean force that is able to balance the electromagnetic interactions of the orbiting electron with a distant ensemble of particles that would otherwise give rise to radiative damping (III).

For the case of circular orbits, the resonant conditions are found to be identical to the integer-action conditions of the original Bohr orbital model. Thus the metron model represents an interesting amalgam of the Bohr orbital model with QED. Details are given in III.

The question remains whether the metron model is able to reproduce atomic spectra to the same high level of accuracy as QED. In detail, the metron interaction computations differ from QED: they contain no closed loop contributions, there should arise no divergences, so that there is no

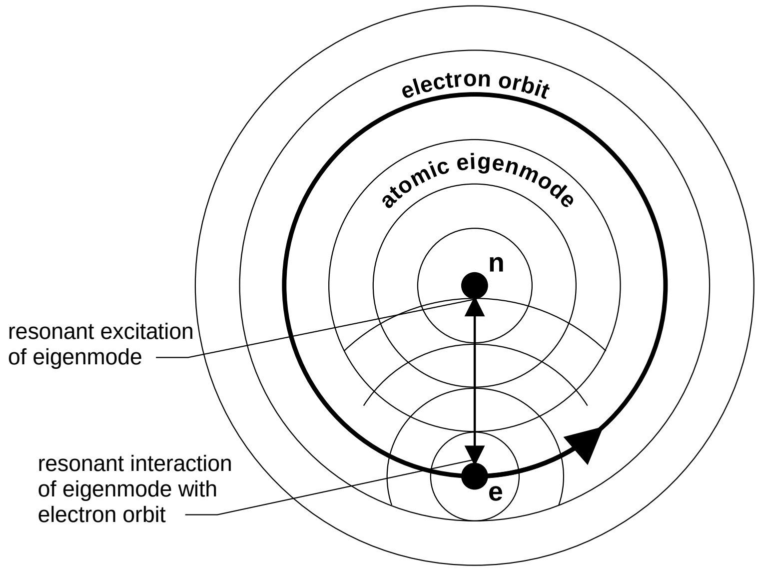

Figure 3: Resonant interactions between an orbiting electron e and the Dirac eigenmode generated by the interaction of the electron's de Broglie field with the atomic nucleus n.

need for a renormalization formalism, and the QED and metron interaction Lagrangians differ at higher order. One can perhaps draw some encouragement from Barut's (1988) claim that classical tree-level computations of the eigenmodes of the Dirac equation (33), without closed loop contributions and renormalization, yield better agreement with measurements than the QED computations. However, Barut's computations, although classical, are also not identical to the metron computations.

I have also not discussed the problem of the transition between eigenmodes through emitted or absorbed radiation. It is shown in III that the coupling of atomic eigenmodes through radiation is governed by the same Maxwell-Dirac field equations in the metron model as in QED. Thus the same eigenfrequency difference relations and selection rules apply in both cases. However, the computation of the transition probabilites involve not only interactions between the eigenmodes and the emitted or absorbed radiation, but also changes in the electron orbits, and are more complex in the metron model than in the QED case.

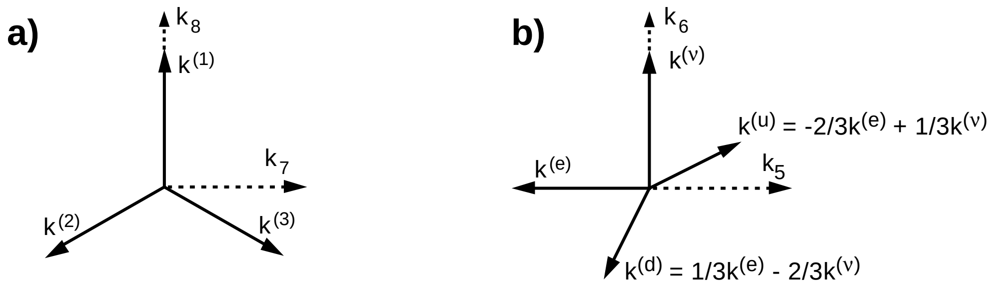

Figure 4: Fermion harmonic wavenumber configurations for (a) the three coloured quarks in the chromodynamic plane k_7, k_8 and (b) the leptons e, ν and quarks u, d in the electroweak plane k_5, k_6 (from IV).

6 The Standard Model

The metron derivation of the coupled field equations and particle distant interactions of the Maxwell-Dirac-Einstein system outlined above can be readily generalized to the remaining weak and strong interactions. For the Maxwell-Dirac-Einstein system, the dimension of harmonic space needed to be at least four to reproduce the 4-spinor Dirac equation (II), but the periodicities of the metron parton components could be restricted to time (k_4) and – as in the original Kaluza-Klein model – a single harmonic dimension (k_5). The wavenumber component k_5 determined the electromagnetic charge, while the frequency k_4, or the particle mass, governed the gravitational coupling. The principal generalization needed to include the two additional forces is the introduction of further partons with periodicities in the other harmonic dimensions.

The algebraic details, described in IV, are rather complex and will not be outlined here. However, the basic geometrical configuration of the metron model needed to reproduce the principal features of the Standard Model – the three families of quarks and leptons, together with their coupling fields, the electroweak bosons and strong-interaction gluons, and the $U(1) \times SU(2) \times SU(U3)$ gauge symmteries – can be readily summarized (see Fig. 4):

- To every parton there exists an anti-parton obtained by reflecting the parton configuration in harmonic space.

- Leptons are represented by partons whose harmonic wavenumber vectors lie in the electroweak plane k_5, k_6. The harmonic wavenumber vectors of the electron, muon and τ particle are oriented parallel to the k_5 axis, the wavenumber vectors of their associated neutrinos parallel to the k_6 axis.

- Quarks are characterized by wavenumber vectors whose major components lie in the colour plane k_7, k_8, but which contain also weak components in the electroweak plane. The wavenumber components in the colour plane describe the strong interaction coupling, while the electroweak components characterize the electroweak splitting between the up/down, charm/strange and top/bottom quark pairs.

- The three Standard Model families are explained as the first three modes (with respect to the radial coordinate in physical space) of the trapped metron eigen-oscillations. According to this picture, there should be no limit to the number of families, although the higher modes presumably become increasingly unstable.

- The three quark colours correspond to three orientations of the quark wavenumber vectors in the colour plane in the form of a symmetrical Mercedes star. Quarks occur always in combinations such that the vector sum of the wavenumber vectors in the colour plane vanishes (the net colour is white). This condition implies that, in addition to the quadratic (difference-wavenumber) self-interaction of individual quarks, the joint interaction of the set of quarks can couple into a mean field (the wave guide) with zero harmonic wavenumber.

- The coupling between quarks is mediated by bosons generated by quadratic difference interactions between quarks. There exist also sum- and higher-order interactions, which have no counterpart in the Standard Model. Thus the Standard Model appears from the viewpoint of the metron model only as an approximation.

- The gauge symmetries of the Standard Model follow from the geometrical symmetries of the parton configurations, in combination with the invariance of the generalized Einstein equations with respect to (n-dimensional) coordinate transformations. However, there exist minor differences between the symmetries of the Standard Model and the metron model (for example, the quark coupling through diagonal and non-diagonal gluons is characterized by different coupling constants in the metron model). The different origin of symmetries in the metron model compared with QFT is fundamental. The Einstein vacuum equations contain no symmetries apart from the invariance with respect to coordinate transformations and the symmetry of the background metric (which in the simplest metron model is isotropic in physical-plus-harmonic space). Thus in contrast to QFT, in which the basic symmetries are introduced *a priori* into the Lagrangians, all symmetries or asymmetries of the metron model (such as the different role of physical spacetime and harmonic space) are properties of the solutions rather than the field equations themselves.

- All 23 empirical constants of the Standard Model follow from the geometrical structure of the metron solutions.

7 Conclusions

As pointed out already by Kaluza and Klein for the case of electromagnetism, the extension of the classical gravitational equations to a higher dimensional space is the simplest way to generalize Einstein's elegant concept of gravity to other forces. The reduction to the vacuum equations (7) simplifies the equations still further. More importantly, this step opens the possibility of explaining rather than postulating the existence of particles and their interactions.

However, a prerequisite for pursuing this avenue is the resolution of the wave-particle duality paradox. This can be achieved within the framework of classical physics, based on the objective existence of both fields and particles, by assuming that particles carry periodic far fields characterized by de Broglie's dispersion relation. Bell's theorem that such hidden-variable theories are necessarily in conflict with the Einstein-Podolsky-Rosen experiment is circumvented by the observation that at the micro-physical level strict time-reversal symmetry applies, as opposed to the existence of an arrow-of-time assumed by Bell. An arrow-of-time arises only at the macrophysical level of irreversible phenomena.

It is rather gratifying that a theory based on these simple concepts is able to reproduce the coupled field equations of quantum field theory at lowest interaction order. In addition, the theory explains the origin and derives the structure of discrete particles, including the internal forces within the particle core and the distant interaction forces of gravity and electromagnetism. In the process, one recovers all fundamental physical constants: Planck's constant, the gravitational coupling, the particle masses and charges, and all other empirical constants of the Standard Model. The origin of the extreme weakness of the gravitational forces is also explained.

However, the metron model outlined in this brief sketch, and developed more fully in the detailed analysis of I-IV, represents still only a skeleton. Plausibility arguments are given in I for the existence of metron solutions with the postulated properties needed to recover (and explain) the principal features of quantum field theory and the elementary particle spectrum as outlined in II-IV. Explicit computations of coupled wave-mode/wave-guide metron-type solutions were furthermore presented in I for a simplified scalar Lagrangian that mirrors the principal nonlinear properties of the Einstein vacuum equations. However, metron solutions for the real n-dimensional gravitational Lagrangian still need to be computed. Work is currently in progress on the numerical determination of metron solutions for n=8.

It is hoped that numerical computations combined with further theoretical analysis will help answer a number of questions that have appeared at the present level of investigation:

1. Are metron solutions, assuming they exist, stable?

2. The metron-type solutions computed in I for a scalar Lagrangian represent a continuum rather than a discrete spectrum. How can one explain the existence of a discrete rather than a continuous spectrum of elementary particles? And why do the solutions exhibit the particular structure that was postulated, in particular a periodicity in one sub-space and locality in another? Is this related to the first question, namely a stability criterion?

3. Although the scattering of particles at a lattice or passing through a slit screen yields qualitatively similar interference patterns in both the metron model and quantum theory, the scattering computations for the two theories probably differ in detail. Can one distinguish experimentally between the two theories?[14]

[14]This is not as straightforward as it may seem, as de Broglie scattering computations

4. Are higher-order metron computations of atomic spectra consistent with experiment and the highly accurate results of quantum electrodynamics?

5. Does the metron model yield the correct transition probabilities for the atomic emission and absorption of radiation?

6. Does the metron model reproduce the Bohr orbital picture not only for circular but also elliptical orbits?

Clearly, there are still many fundamental questions to be answered. However, the ability to reproduce and explain a broad spectrum of basic microphysical phenomena within the framework of a unified classical "objective" physical theory, starting only from the deceptively innocuous Einstein vacuum equations $R_{LM} = 0$ in an 8-dimensional space, is at least an encouraging first step towards realizing Einstein's dream of the unification of all forces of nature in a single deterministic theory.

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References

[1] Ashtekar, A. (1988) *New Perspektives in Canonical Gravity.* Bibliopolis, Naples, 324pp.

[2] Bell, J.S. (1964) On the Einstein-Podolsky-Rosen Paradox. Physics, *1*, 195-200.

[3] Barut, A.O. (1988) Quantum-electrodynamics based on self-energy. Physica Scripta, *T21*, 18-21.

are normally carried out in the inverse mode: the interaction potential is inferred from the interference pattern.

[4] Bohm, D. (1952) A suggested interpretation of the quantum theory in terms of "hidden" variables. Phys.Rev.,*85*, 166- 179, 180-193.

[5] de Broglie, L. (1956) *Une tentativè d'interpretation causale et non linéaire de la méchanique ondulataire: la théorie de la double solution*. Guathier-Villars, Paris, 297pp.

[6] Einstein, A. (1909) Zum gegenwärtigen Stand des Strahlungsproblems. Physik.Z.,*10*, 185-193.

[7] Garrett, C. (1976) Generation of Langmuir circulation by surface waves - a feedback mechanism. J.Phys.Oceanogr.,*6*, 925-930

[8] Gutzwiller, M.C. (1990) *Chaos in Classical and Quantum Mechanics*, Springer, 432pp.

[9] Haines, K. and P. Malanotte-Rizzoli (1991) Isolated anomalies in westerly jet streams: a unified approach. J.Atmosph.Sc.,*48*, 510-526

[10] Hasselmann, K. (1966) Feynman diagrams and interaction rules of wave-wave scattering processes. Rev. Geophys.,*4*, 1-32

[11] Hasselmann, K. (1996a) The metron model: Elements of a unified deterministic theory of fields and particles. Part 1: The Metron Concept. Physics Essays,*9*, 311-325.

[12] Hasselmann, K. (1996b) The metron model: Elements of a unified deterministic theory of fields and particles. Part 2: The Maxwell Dirac- Einstein System. Physics Essays, *9*, 460-475.

[13] Hasselmann, K., (1997a) The metron model: Elements of a unified deterministic theory of fields and particles. Part 3: Quantum Phenomena. Physics Essays, *10*, 64-86.

[14] Hasselmann, K.(1997b) The metron model: Elements of a unified deterministic theory of fields and particles. Part 4: The standard Model. Physics Essays, *10*, 269-286.

[15] Kaluza, Th. (1921) Zum Unitätsproblem der Physik. Akad.Wiss.Berlin, 966-972

[16] Klein, O. (1926) Quantentheorie und fünfdimensionale Relativitätstheorie. Z.Phys., *37*, 895-906

[17] Lorentz, H.A. (1904) Elektronentheorie, Enzykl. math. Wiss., *5*, Heft 1, Leipzig.

[18] Miaini, L. and R.A. Ricci, eds. (1996) Symposium in Honour of Antonino Zichichi to Celebrate the 30'th Anniversary of The Discovery of Nuclear Antimatter, Italian Physical Soc., Conf.Proc. *53*, Bologna, pp.18,125,132

[19] Wheeler, J.A., and R.P. Feynman (1949) Classical electrodynamics in terms of direct particle interaction. Rev.Mod.Phys.*21*, 425-433