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No need for dark-matter, dark-energy or inflation, once ordinary matter is properly represented?

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Abstract

In a recent *Foundations of Physics* paper [5] by the current author it was shown that, when the self-force problem of classical electrodynamics is properly solved, it becomes a plausible ontology underlying the statistical description of quantum mechanics. In the current paper we extend this result, showing that ordinary matter, thus represented, possibly suffices in explaining the outstanding observations currently requiring for this task the contrived notions of dark-matter, dark-energy and inflation. The single mandatory 'fix' to classical electrodynamics, demystifying both very small and very large scale physics, should be contrasted with other adhoc solutions to either problems. Instrumental to our cosmological model is scale covariance (and 'spontaneous breaking' thereof), a formal symmetry of classical electrodynamics treated on equal footing with its Poincaré covariance, which is incompatible with the (absolute) metrical attributes of the GR metric tensor.

Keywords: dark-matter; dark-energy; inflation; scale covariance; foundations of general relativity; foundations of quantum gravity.

1 Introduction

At the turn of the twentieth century, classical electrodynamics (CE) was the only game in town. Following Einstein's resolution of its Galilean non covariance, one could have thought that a theory-of-everything was just around the corner. And yet, to paraphrase Kelvin, a few dark clouds hovered over CE:

1. CE, by itself, was dead wrong. Freely moving charges in a lab, trace parabolas rather than straight lines. CE needed Newton's gravity by its side, with its distinct (Galilei rather than Lorentz) symmetry group, making it impossible to merge the two into a consistent theory.

2. CE was mathematically ill defined, due to the so-called classical self-force problem: Both the Lorentz force equation of a point charge, as well as the total energy of a group of interacting point charges, are ill defined [3].

3. CE was not generally covariant. The coordinates appearing in CE's Minkowskian form are merely abstractions of physical entities—rods and clocks; Nature is not 'marked' with coordinates. Were CE's Minkowskian form a fundamental description of nature, then those physical entities could have been explicitly described using its equations, leading to an infinite recursion. The only consistent way coordinates can enter a fundamental description of nature is as 'scaffolding', used in calculating the 'real thing': A measurement; Some (dimensionless) number. A particularly simple way of guaranteeing the scaffolding independence of the real thing, is to make CE's equations look the same in any coordinate system, identifying the results of measurements with certain (coordinate independent) scalars. The principle of general covariance, which creeped into physics as a mathematical corollary of Einstein's field equations, could have therefore been proclaimed much earlier.

4. CE began showing some discrepancies with observations, currently understood as QM phenomena, with no apparent resolution in sight.

In 1905, therefore, CE was no more than a rough sketch, or first draft of a theory, certainly not a mature one. It worked so well despite its internal inconsistencies simply because it was tested in a rather limited domain, where ad hoc 'cheats' enabled the extraction of definite results from an ill defined, conceptually flawed mathematical apparatus. When the domain of CE was subsequently extended, and no cheating method would lead to the experimental result anymore, the demise of CE began, and alternatives sprung. In the current paper we argue that, seeking alternatives to a successful non-theory, is a bad methodology; Physicists at the first quarter of the twentieth century should have first properly fixed CE, preserving those of its features responsible for its success, and only then figured what else, if anything, was needed in physics.

As it turns out, such proper fixing is indeed possible. A solution to the non covariance problem begins with the standard procedure of expressing differential equations in curvilinear coordinates, ξ^μ. Given CE's Minkowsian form in coordinates x^μ, assumed a valid description of nature in *some* cases, each new coordinate system introduces a symmetric transformation matrix

$$g_{\mu\nu}=\frac{\partial x^\alpha}{\partial \xi^\mu}\frac{\partial x^\beta}{\partial \xi^\nu}\eta_{\alpha\beta}\,,\qquad \eta=\mathrm{diag}(1,-1,-1,-1)\,,$$

completely encoding the effect of the transformation. The geodesic equation then becomes just the Lorentz force equation in empty space, expressed in curvilinear coordinates. However, $g_{\mu\nu}$—ten independent functions—is an infinite set of parameters, changing from one coordinate system to another, which is exactly the definition of an equation not being covariant with respect to a group of transformations[1]. The standard way of coping with such non covariance is to elevate the status of those parameters to that of dynamical variables[2]. Further recalling that, by its definition, $g_{\mu\nu}$ transforms as a second rank tensor, the simplest non-trivial covariant choice for the equation to be satisfied by $g_{\mu\nu}$ is Einstein's field equations

$$AR_{\mu\nu}+Bg_{\mu\nu}R+Cg_{\mu\nu}=P_{\mu\nu}\,, \tag{1}$$

with $R_{\mu\nu}$ and R the once and twice contracted Riemann tensor, $P_{\mu\nu}$ the total energy-momentum tensor of matter+radiation, and A,B,C some constants to be determined by observations (Between 1915 and 1919, Einstein himself had already proposed three different sets of constants). No dark-energy, no geometry, viz., $g_{\mu\nu}$ has no a priori metrical meaning,

[1] For example, expressing $g_{\mu\nu}$ as a Fourier sum, the equations look the same in any coordinate system, only with different Fourier coefficients.

[2] For example, treating a Hydrogen atom as a two body system rather than an electron in an external potential, restores translation covariance. The proton's coordinates, parameters in the single body treatment, become dynamical variables.

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and no equivalence principle[3]. This is, of course, much easier to recognize in hindsight, but the point stands: not only special relativity is buried in CE (as attested by the title of Einstein's first paper on relativity) but also general relativity (GR). A solution of problem 1 is therefore a corollary of the solution to 3; CE+gravity is just generally covariant CE.

Remarkably, problem 2—the classical self-force problem—has never been properly solved despite a century of extensive research. By 'proper' we mean a mathematically well defined realization of the *basic tenets of CE* which are responsible for its immense success: Maxwell's equations and local energy-momentum (e-m) conservation. A recently proposed novel mathematical construction, dubbed extended charge dynamics (ECD), first appearing in [4] and then fine tuned in [3], provides such a proper solution, and will be briefly discussed in section 2.

There remains problem 4. In [5] is was shown that a proper solution to 1–3, namely generally covariant ECD, leads to a new problem: Statistical aspects of ensembles of ECD solutions, such as those involved in a scattering experiment, cannot be read from ECD alone, requiring a complementary statistical theory. It is argued there that quantum mechanics is that missing complementary statistical theory, which solves problem 4. With the advent of QM, the associated conceptual difficulties became an issue also in astronomy: It is no longer clear what to put on the r.h.s. of (1) in the first place.[4] ECD's resolution of those difficulties imply, among else, that no approximation is involved in using the classical e-m tensor on the r.h.s. of (1).

With CE's original four problems apparently solved, we fast-forward the evolution of twentieth century physics, reviewing it in the new light shed by ECD. In section 3, dealing with particle physics, we briefly sketch the results of [5] regarding the so-called block-universe (BU) view, mandated by both SR and GR. A clear distinction is drawn between the (classical) *ontology* of the BU, allegedly ECD, and various statistical descriptions thereof, such as the standard model of particle physics. Section 3.1, presenting a tentative model of matter based solely on ECD, is not crucial for the understanding of the rest of the paper, and may be skipped on first reading. It is included, nonetheless, since ECD, or some close relative thereof, *must* be the ontology in the BU for our conjectured cosmological model to be valid. Along the way, simple explanations are provided to persistent mysteries in particle physics, such as the quantization of the electric charge (see conclusion section, 5, for the main such

[3]More accurately, rather than being a separate postulate, the equivalence principle is a simple corollary of general covariance. It can be shown that, around any spacetime point, x, a local coordinate system, y, exists for which $g_{\mu\nu}|_x = \eta_{\mu\nu}$ and $\partial_\alpha g_{\mu\nu}|_x = 0$. The geodesic equation at x then has the form $\ddot{y}^\mu = 0$ with 'dot' standing for derivative with respect to proper-time. It then follows that, to the extent the above special form of the geodesic equation implies free fall, and insofar as the second derivatives of the metric are negligible, the Minkowskian form of CE locally holds true in a freely falling frame.

[4]One can find a host of ill motivated proposals, such as using the e-m tensor derived from a Dirac field, notwithstanding the Dirac field being a representation of a single particle! Or to use the expectation value with respect to some 'universal wave function(al)' of the (operator valued-) e-m tensor associated with some quantum field. Now, in standard QM, the expectation value of an operator represents certain repeated measurements associated with it, averaged over an ensemble represented by the wave-function. As there is only a single universe, it is therefore unclear what that expectation value stands for, let alone who is doing the measurement.

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points).

We then move to more contemporary issues in astronomy where, even with all the extra machinery of high-energy physics, no reasonable explanation can be given to key observations. It is shown that generally covariant ECD alone, provides a transparent explanation to phenomena currently requiring dark-matter to this end, further tying it to seemingly unrelated QM phenomena. A simple ECD based Friedman model is then derived, resulting in a cosmological model which is free of both the flatness and horizon problems, plaguing the historical 'big-bang' model. The contrived mechanism of inflation is thus rendered moot, as is the need for inflationary dark-energy.

Instrumental to our cosmological model is ECD's scale covariance, a formal symmetry of CE which we consider to be just as important as its Poincaré covariance. Nonetheless, the fact that, local (Minkowskian-) physics does not manifest a continuum of, e.g., Bohr radii (as oppose to a continuum of atomic positions or velocities), implies a so-called spontaneous scaling symmetry breaking, whose origin is analyzed in detail. The result is a complete reinterpretation of all astronomical data concerning cosmology.

Finally, a note regarding the broader context of the paper. For the past eighty years or so, progress in physics consisted mostly of a series of 'epicycles', each added in response to a discordant observation. This natural process, enjoying the merit of 'backward compatibility', can either continue forever or else stagnate, as the task of adding an epicycle becomes harder due to an expanding experimental body of knowledge. Those believing that the latter scenario had occurred, hence that the time is ripe to consider a paradigm shift, are still a minority among physicists, but their number is steadily increasing, and for good reasons. Now, the problem with a paper advocating a paradigm shift, is that it would be futile to zoom-in on an isolated patch of the big picture; One's proposal could elegantly solve a conundrum in one domain, but clash with observations in another, or even lack extensions thereto (MOND being such an example; The entire program of particle physics, explaining but a tiny fraction of the observed universe, is to a large extent, another). Instead, it has to depict an alternative panoramic picture, hopefully convincing that a genuine landscape could lie behind it. The reader is therefore warned that, given obvious resource limitations, the picture he/she is about to see is, in part, of low resolution compared with the norm adhered to in standard, domain specific scientific publications.

2 Extended charge dynamics (ECD) in brief

First appearing in [4] and then fine-tuned and related to the self-force problem in [3], ECD is a concrete realization of the two obvious pillars of classical electrodynamics (CE) referred to as the *basic tenets of CE*, which are: Maxwell's equations in the presence of a conserved[5] source due to all particles (labelled by $a = 1 \dots n$)

$$\partial_\nu F^{\nu\mu} \equiv \partial^\nu \partial_\nu A^\mu - \partial^\mu \partial_\nu A^\nu = \sum_a j^{(a)\,\mu} \,, \tag{2}$$

[5] The antisymmetry of F implies that solutions of Maxwell's equations exist for a conserved source only.

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$$\partial_\mu j^{(a)\,\mu} = 0\,, \tag{3}$$

with $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$ the antisymmetric Faraday tensor, and local 'Lorentz force equation'

$$\partial_\nu\, T^{(a)\,\nu\mu} = F^{\mu\nu}\, j^{(a)}{}_\nu\,, \tag{4}$$

with $T^{(a)}$ the symmetrical 'matter' e-m tensor associated with particle a. Defining the *canonical tensor*

$$\Theta^{\nu\mu} = \frac{1}{4} g^{\nu\mu} F^{\rho\lambda} F_{\rho\lambda} + F^{\nu\rho} F_\rho{}^\mu\,, \tag{5}$$

we get from (2) and (5) Poynting's theorem

$$\partial_\nu \Theta^{\nu\mu} = -F^\mu_{\ \nu} \sum_a j^{(a)\,\nu}\,. \tag{6}$$

Summing (4) over a and adding to (6) we get local e-m conservation

$$P := \Theta + \sum_a T^{(a)} \quad \Rightarrow \quad \partial_\nu P^{\nu\mu} = 0\,, \tag{7}$$

and, purely by the symmetry and conservation of $P^{\nu\mu}$, also generalized angular momentum conservation

$$\partial_\mu \mathcal{J}^{\mu\nu\rho} = 0\,, \quad \mathcal{J}^{\mu\nu\rho} = \epsilon^{\nu\rho\lambda\sigma} P^\mu_{\ \sigma} x_\lambda\,. \tag{8}$$

As shown in [3], for $j^{(a)}$ and $T^{(a)}$ co-supported on a common world-line, corresponding to 'point-particle' CE, no realization of the basic tenets (2)&(4) exists. Their ECD realization therefore involves j and T extending beyond this line support yet still localized about it, representing what can be called 'extended particles' with non-rigid internal structures. Nevertheless, the reader must not take too literally this name, as both j and T associated with distinct particles are allowed to overlap or cross one another which is a critical point in our subsequent analysis. Moreover, the magnetic dipole moment and the angular momentum associated with a single spin-$\frac{1}{2}$ ECD particle at rest, have a fixed non vanishing value which cannot be 'turned off', viz., that particle is not some 'rotating, electrically charged liquid drop' eventually dissipating its angular momentum and magnetic dipole. Finally, it is stressed that the ECD objects carrying a particle label, such as $j^{(a)}$ and $T^{(a)}$, collectively dubbed *particle densities*, should not be viewed as time-varying three dimensional extended distributions but, rather, as covariant four dimensional 'extended world-lines'. This point, too, is critical.

As shown in appendix D of [3], when a charged body is moving in a weak external EM field which is slowly varying over the extent of the body, a coarse description of its path is given by solutions of the Lorentz force equation in that field. This is a direct consequence of the basic tenets hence the name 'local Lorentz force equation' given to (4). In the presence of a strong or rapidly varying external field, however, a general ECD solution, whether representing a single (elementary-) particle or a bound aggregate thereof (composite particle), not only does it have additional attributes besides its average position in space, facilitated by its extended structure, but moreover, even its coarse path could deviate substantially from the Lorentz

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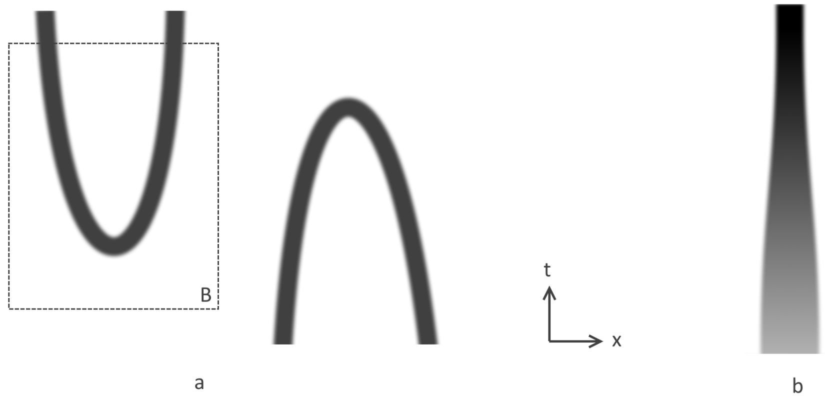

Figure 1: Non classical scenarios for ECD particles. (a) Creation and annihilation of a pair. (b) Scale transition (the varying gray-level represents charge density)

force law. In particular, ECD paths could look like those depicted in figure 1a. Applying Stoke's theorem to local charge conservation (3) and box B in figure 1a, we see that the two created/annihilated particles must be of opposite charges. However, the reader should not rush to a conclusion that those are a particle-antiparticle pair despite ECD's 'CPT' symmetry

$$\begin{gathered} A(x) \mapsto -A(-x)\,, \quad j(x) \mapsto -j(-x)\,, \quad T(x) \mapsto T(-x) \quad \Longrightarrow \\ P(x) \mapsto P(-x)\,, \quad \mathcal{J}(x) \mapsto -\mathcal{J}(-x)\,. \end{gathered} \tag{9}$$

It is only when the two 'branches' are sufficiently removed from each other, and have attained some metastable state, that a particle-type label can be assigned to them and it may very well be that this never happens. Either branch could end up part of a composite particle before stabilizing. This offers a particularly simple explanation for the observed imbalance between matter and antimatter.

Applying Stoke's theorem to e-m conservation (7) and box B, we further see that the disappearance/emergence of mechanical e-m must be balanced by either a corresponding release/absorption of EM e-m or else by the creation/annihilation of another pair (or pairs).

2.1 Advanced solutions of Maxwell's equations

In a universe in which no particles implies no EM field, a solution of Maxwell's equations is uniquely determined by the conserved current, j. The most general such dependence which is both Lorentz and gauge covariant takes the form

$$A^\mu(x) = \int d^4x' \left[\alpha_{\text{ret}}(x') K_{\text{ret}}{}^{\mu\nu}(x-x') + \alpha_{\text{adv}}(x') K_{\text{adv}}{}^{\mu\nu}(x-x')\right] j_\nu(x')\,, \tag{10}$$

for some (Lorentz invariant) spacetime dependent functionals, α's, of the current j, constrained by $\alpha_{\text{ret}} + \alpha_{\text{adv}} \equiv 1$, where $K_{\substack{\text{ret}\\ \text{adv}}}$ are the advanced and retarded Green's function of

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(2), defined by [6]

$$\left(g_{\mu\nu}\partial^2 - \partial_\mu\partial_\nu\right) K_{\substack{\text{ret}\\ \text{adv}}}{}^{\nu\lambda}(x) = g_\mu{}^\lambda \delta^{(4)}(x)\,, \tag{11}$$

$$K_{\substack{\text{ret}\\ \text{adv}}}(x) = 0 \quad \text{for} \;\; x^0 \lessgtr 0\,. \tag{12}$$

The standard proviso, $\alpha_{\text{adv}} \equiv 0$, added to CE, not only is it not implied by the observed arrow-of-time [3][5], but moreover, it even turns out to be incompatible with ECD. In other words, one cannot impose a choice of α's on ECD currents but, instead, read the choice from a global consistent solution, involving fields and currents.

The asymmetry between advanced and retarded solutions, manifested in the arrow-of-time (AOT) is intimately related to ECD's CPT symmetry 9. That is, for our universe to have an oppositely pointing AOT, it would also need to have every particle replaced with its antiparticle. In section 4.2.3 we mention a scenario where this may be the case. We shall further return to the AOT in section 3.1.4 dealing with the explanation given by ECD to photon related phenomena.

2.2 Scale covariance

Scale covariance is just as natural a symmetry as translation covariance. A fundamental description of nature should therefore not include a privileged length scale, just as it should better not include a privileged position. ECD is scale covariant by virtue of its symmetry [7]

$$\begin{aligned} &A(x) \mapsto \lambda^{-1} A\left(\lambda^{-1} x\right)\,, \quad j(x) \mapsto \lambda^{-3} j\left(\lambda^{-1} x\right)\,, \quad T(x) \mapsto \lambda^{-4} T\left(\lambda^{-1} x\right) \\ \Longrightarrow\; &\Theta(x) \mapsto \lambda^{-4}\Theta\left(\lambda^{-1} x\right)\,, \quad P(x) \mapsto \lambda^{-4} P\left(\lambda^{-1} x\right)\,, \quad \mathcal{J}(x) \mapsto \lambda^{-3}\mathcal{J}\left(\lambda^{-1} x\right)\,, \end{aligned} \tag{13}$$

with the two free parameters of ECD unchanged. The exponent of λ is referred to as the *scaling dimension* of a density hence, by definition, it is 0 for those two ECD parameters. The scale factor, λ, which in the present context is taken to be positive, can, in fact, be an arbitrary non vanishing real number thereby merging scaling symmetry with CPT symmetry (9).

ECD, however, takes scale covariance one step beyond the formal symmetry (13) (cf. section 1.2 and 2 in [4] dealing with scale covariance of point-particle CE). ECD particles can *dynamically* undergo a scale transformation, as illustrated in figure 1b. In section 2.3 next, we discuss a mechanism allegedly 'fixing' the scale of all particles of the same specie to their common value. And yet, we shall argue in both contexts of particle physics and cosmology, that we actually do observe also scaled versions of those particles.

When shifting to a different scale, the electric charge of a particle, whether elementary or composite, does not change by virtue of scale invariance of electric charge $\int \mathrm{d}^3x\, j^0$. In contrast, the scaling dimension of the particle's magnetic dipole moment $\mu_i = \frac{1}{2}\int \mathrm{d}^3x\, \epsilon_{ijk} x^j j^k$ is 1, hence scale dependent. If, further, the particle is sufficiently isolated then, since the

[6] More accurately, (11) and (12) do not uniquely define K but the remaining freedom can be shown to translate via (10) to a gauge transformation $A \mapsto A + \partial\Lambda$, consistent with the gauge covariance of ECD.

[7] More accurately: If $\{A, j, T\}$ is a triplet associated with a valid ECD solution, then so is the scaled triplet, given in (13), whose associated valid ECD solution is defined in [3].

EM field in its neighbourhood is dominated by its electric current, one can associate the global e-m tensor P (7) in that neighbourhood with the particle (or particles in the case of a composite), referring to it as $P^{(a)}$. The particle's self energy (or mass), $\int \mathrm{d}^3x\, P^{(a)\,00}$, incorporating also the EM self-energy which is a finite quantity in ECD, therefore has scaling dimension -1, while its three dimensional angular momentum, $J_\imath = \int \mathrm{d}^3x\, \epsilon_{\imath\jmath k} x_\jmath P^{(a)\,0k}$ is scale invariant. All these scaling dimensions become critical in section 3, dealing with the consequences of scale transitions.

2.3 The Zero Point Field and broken scale covariance

As advanced and retarded solutions of Maxwell's equations are treated on equal footings, a radiating system can maintain a constant time-averaged energy level, with advanced fields compensating for the loss due to retarded fields. In fact, it is such a dynamical equilibrium, rather than a 'frozen', non radiating one, minimizing the potential energy of the system, which is expected in a universe containing both type of solutions. Moreover, the *same* equilibrium state should characterize all systems of a given type in a universe which is homogeneous on sufficiently large scales.

To see why this last statement should be true, let us first take a closer look at the global EM field, F, created in such a universe at a point $\boldsymbol{x}$ in space, void of any matter. Clearly, F is due to all particles in the universe, containing both advanced and retarded components, and its form at $x \equiv (t, \boldsymbol{x})$ is determined by the form of all currents at their intersection with the light cone of x. Focusing on two spherical, constant-time slices of this light-cone—one from its future part and one from its past—of large radius r, realistically assumed to be intersected by incoherently radiating currents, we look at their time dependent contribution to F at $\boldsymbol{x}$ as a function of t. Collecting our assumptions, the following can be said of F, seen as a random process:

1. F is isotropic, implying that the expectation value of any derived three-tensor must be invariant under rotations. In particular, the (magnetic) three-tensor $\langle F^{ij}\rangle$, must vanish, as well as the (electric) three-vector $\langle F^{i0}\rangle$ and the Poynting vector, $\langle \boldsymbol{E}\times\boldsymbol{B}\rangle$. F is further some Gaussian process (by the law of large numbers).

2. Three-tensors bilinear in F, such as the (scalar) energy density $\frac{1}{2}(\boldsymbol{E}^2+\boldsymbol{B}^2)$, all have an r-independent expectation value. This is so because the r^{-1} dependence of a radiation field, when squared, cancels with the number of currents intersecting each sphere, which grows as r^2.

It follows that in a universe which is homogeneously filled with matter on sufficiently large scales, the contributions to F from different spheres are all of the same magnitude, making the ZPF a genuine attribute of the entire universe. In a static infinite universe, it would seem that $\langle F^2\rangle$ should therefore diverge everywhere. In section 4.2, however, we shall argue that the contributions of different shells cannot be independent due to interference effects, preventing such a catastrophe.

If we now place a system comprising charged matter (e.g., a Hydrogen atom, but we shall later argue that *all* matter is charged matter) at $\boldsymbol{x}$, we can safely assume that far away from the system, the overall character of the global EM field will not be changed. In the

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immediate vicinity of the system, in contrast, the EM field generated by the system cannot be neglected. We shall refer to that 'universal part' of the EM field, due to all other particles as the *zero point field* (ZPF) at x, a name borrowed from stochastic electrodynamics (SED), although it does not represent identical objects (see [5]), and to the field generated by the distinguished system as the *self-field* of the system [8] .

The equilibrium state eventually attained by the distinguished system at $\boldsymbol{x}$, would depend solely on time-invariant attributes of the system, such as the number of its constituent particles, and on the statistical character of the ZPF around $\boldsymbol{x}$. As the latter is independent of $\boldsymbol{x}$ in a homogeneous universe, it follows that all systems with the same invariants attain a common equilibrium with the ZPF. But this passive equilibrium also has an active facet: All such systems radiate a very specific self-field, collectively generating the ZPF, hence the name: The ZPF is due to all systems in equilibrium, the ground state obviously being the dominant one. This includes any freely moving elementary (or composite) particle of a given type, whose rest-energy, or rather its time-averaged rest-energy, becomes one and the same throughout the universe, notwithstanding ECD's scale covariance.

A crucial feature of the ZPF, as the redistributer of e-m in the universe, imposing thereby a common equilibrium state on all identical systems, is that it combines both advanced and retarded fields. Had particles generated only retarded fields (as in SED), the universe would have had to be much smaller and more opaque for our equilibrium hypothesis to be plausible. Indeed, a system loosing e-m to retarded radiation would feel the reaction of a shell with radius r light-years, only $2r$ years later (precisely for this reason the CMB is attributed to a dense epoch in the history of the universe rather than to the current one). With advanced fields included, in contrast, the reaction is instantaneous (see also figure 2 in [5]).

As one gradually gets closer to some concentration of matter, the local statistical properties of the ZPF become increasingly more dependent on the specific form of that matter's distribution (equivalently, the contribution of self-fields adjunct to particles in that matter concentration, becomes more pronounced). In [5] it was shown how such matter-induced modulations of the ZPF are incorporated into QM wave equations, constituting the mechanism by which a particle can 'remotely sense' a distant object, such as the status of the slit not taken by it in a double slit experiment. In section 4.1 we shall argue that those modulations in the ZPF further offer an appealing explanation for 'dark-matter'. Finally, in section 4.2 we 'close the loop', tying the very small with the very large; The preferred scale, such the Compton's length, resulting from scaling symmetry breaking, is completely arbitrary in Minkowski's space, but not so in a Friedman universe, where the ZPF is a source of cosmological curvature. With the loop closed, a radically different interpretation of astronomical data ensues.

3 ECD and Particle physics

If asked about the nature of the atomic world, a chemist would reply roughly as follows: Matter is made out of heavy, positively charged nuclei, with light, negatively charged electrons

[8]The decomposition (10) uniquely attaches a self-field to each particle.

frenetically moving in between them, thereby countering the electrostatic repulsion between the nuclei (why the electrons do not radiate their energy and spiral towards a nucleus—he doesn't know nor care). Schröedinger's equation simply describes the time-averaged joint charge distribution of those constituents which, for stable molecules, should indeed be time independent.

On hearing the chemist's reply, a physicist would object that such a description cannot possibly be what is *really* happening. For when a molecule is ionized, the Schrödinger wave-function of even a single electron gets spread over a huge region, which is incompatible with a particle description of an electron. When, furthermore, two electrons are ejected in an ionization process, the chemists picture makes even less sense.

In [5] it is shown that the chemist's simple and intuitive picture is consistent with everything physicists know about Schröedinger's equation and atomic physics alike, including quintessentially quantum mechanical phenomena such as those involving entanglement, spin-$\frac{1}{2}$ and even photons. Moreover, the chemist's disregard to radiation losses is fully warranted, while the physicist's problem with the spread of the wave-function stems from a confusion between time and ensemble averages: The charge of an electron is, indeed, confined to a tiny region. The multi-particle wave-function describes the joint charge distribution of an ensemble of *different* systems, but in (quasi-) equilibrium scenarios, and there only, such as those often described in chemistry, the, ensemble averages can be replaced by time averages of a *single* system, much like in statistical mechanics of ergodic systems.

There is not a single experimental evidence, we argue in this section, suggesting that the chemist's picture should not apply to the subatomic domain and particle physics in general, and that additional interaction modes beyond the EM one, at all exist on those smaller scales. In other words, the ontology of particle and nuclear physics could still be that of classical electrodynamics provided, of course, classical electrodynamics is given a consistent meaning which is what ECD is all about.

So why don't we apply the chemist's methods also to atomic nuclei and particle physics in general? After all, it is remarkably efficient compared with the standard model of particle physics—which, one must add, is almost useless when it comes to nuclear physics: A single multi-particle Schrödinger's equation, with three tunable parameters, capable of describing the morphology, strength, and other physical and chemical properties of millions of different complex molecules, compared with the standard model whose mathematical structure is astronomically more complicated (and ugly some would say) and whose output is comparatively lame—resonance energies, lifetimes, and cross sections.

The reason for the failure of the chemist's description on subatomic scales, we argue, is not that a different ontology characterizes the subatomic domain but, rather, that Schrödinger's equation, and QM wave equations in general, are applicable only in those cases in which the effects of self EM interaction can be 'absorbed' into the parameters of the equation, and it just happens that this is the case at the atomic scale, but not on the much smaller scale involved in nuclear/particle physics. More precisely, we showed in [5] that for QM wave equations to properly incorporate self-interaction, their associated charge distribution must be much wider than the width of the (extended) particle they describe. It should therefore

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not come as a surprise that the constituents of a proton, for example, densely packed into a tiny volume compared with that of an atom, do not necessarily satisfy this condition (see bellow).

The collapse of Schrödinger's description at subatomic scales is so colossal, that one has to basically work out from scratch a new statistical theory, treating self EM interaction non perturbatively (unlike in QED). If ECD is indeed a valid description of the subatomic ontology, then settling for the lame phenomenology provided by the standard model would be tantamount to keep using Ptolmaic epicycles in contemporary astrophysics—a fairly accurate description, but extremely limited in its scope. Regrettably, this is easier said than done.

3.1 A tentative ontology based solely on ECD

In light of the above introduction, it is stressed again that the following is *not* a proposed substitute to the standard model of particle physics but, rather, a proposed ontology, possibly underlying the statistical predictions of the standard model.

3.1.1 Charged leptons

Electrons and their antiparticles, positrons, are the only stable elementary particles in our model, represented by a single particle ECD solution ([3] sec. 3.2). Conversely, it is assumed that no charged, isolated, stable single particle ECD solution exists, other than that representing an electron.

The spin of the electron does not necessarily involve spin-$\frac{1}{2}$ ECD ([3] appendix E) and may be due to an internal current in a scalar ECD solution. Which of the two will be decided by explicit calculations.

As the EM field in an electron's immediate neighborhood is dominated by its self-field, the ZPF (the part of the EM due to all particles but the isolated electron) is ignored in a first approximation, restoring thereby ECD's scale covariance, and our electronic ECD solution is defined only up to a scale transformation (13). It is conjectured, then, that the ECD solutions representing the μ and τ leptons, are just scaled versions of the electroinic solution, with their respective Compton lengths, $\hbar/(mc)$, being the characteristic size of their associated distributions. As explained in [5], an extended electron model, not only does it not conflict with experiment, but it can remove known inconsistencies from Dirac's equation.

A clear support for the above scaling conjecture comes from a few simple observations which, in the standard model, appear simply as axioms. Recalling form section 2.2 the scaling dimensions of the electric charge (0), angular momentum (0), magnetic dipole moment (1), and of the self-energy (-1), the fact that all charged leptons share a common charge and intrinsic angular momentum, but differ on their magnetic moment by a factor which is inversely proportional to their mass, receives a simple explanation.

The role of the neglected ZPF in our model is to give each of the scaled solutions an effective life-time (and a tiny corrections to their $g = 2$ gyromagnetic constant), and only three apparently make it to an observable level. The fact that, different scaled versions have different lifetimes, is clearly a bias of the ZPF which is *not* expected to be scale-invariant, given that every other aspect of our universe is not scale invariant either.

3.1.2 Hadrons

Hadrons are speculated to be composite, rather than elementary ECD particles. The notion of 'composite' in ECD, however, has a very different meaning from its standard-model counterpart, where it stands for a bound aggregate of elementary particles, such as quarks, each with definite autonomous attributes. Instead, it represents a multi-particle bound solution of the ECD equations. The distinction is critical because of the highly nonlinear nature of ECD. When elementary ECD particle cluster to form a composite, possibly overlapping, that nonlinearity renders their previous attributes completely irrelevant, and a genuinely new type of particle is formed.

There is, however, one exception to the above identity loss on the part of elementary ECD particles: Electric charge, which is the only conserved quantity associated with individual particles. It follows that if each constituent of a composite is *somewhere* along its (extended) world-line a free electron/positron, then the common quantization of the electric charge in all particles is trivially explained. The equality in magnitude between the electron's and the proton's electric charges, which is verified to the utmost precision by the overall electric neutrality of ordinary matter, appears in the standard model as an ad hoc postulate involving electrons' and quarks' charges, and must trouble any physicist seeking simplicity in the laws of nature.

Deep inelastic scattering experiments suggests, on the contrary, that the constituents of hadrons have an electric charge, which is either a third or two thirds in magnitude, of the charge of an electron (although it must be remembered that the interpretation of such indirect observations is only meaningful when viewed through the lens of a theoretical framework which, in this case, is different from ours). While it is, in principle, possible that, as in the standard model, the ECD constituents of hadrons never appear as free isolated particles, hence their electric charge needs not equal to that of electrons, this seems like a highly contrived option given that there is no apparent reason for those two arbitrary ratios—a third and two thirds. A more plausible explanation is that the overlap between those constituents creates an effective non uniform charge distribution, with each 'peek' supporting either a third or two thirds of the electron's charge[9].

Now that the relation between elementary and composite ECD particles is established,

[9] A simple model for a proton supporting this picture would be two positive particles, with a single negative one symmetrically placed in between them. Looking at the electrostatic energy of such a system (a finite quantity in ECD), two limits are trivially deduced: if the two positive particles have no overlap with the central negative one, getting them closer reduces the energy. On the other hand, if the two overlap with the negative particle so as to exactly cancel its charge, we get two positive charges of half a lepton charge, with a neutral space in between them. The resulting mutual repulsion between the two partially charged particles tells us that the energy would decrease when the two are moved further apart. Such movement, in turn, would increase the charge of each positive particle beyond half and restore some of the negative charge of the central particle. Thus a minimum energy state somewhere in between those two limits, such as a $+2/3, -1/3, +2/3$ charge distribution, is consistent with our model.

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we can see in more details why QM wave equations cannot describe hadrons. Concretely, an ECD proton is supposed to comprise two positively charged ECD particles and a negative one, all fitting into a ball of radius $R \sim 10^{-15}$m. Given that the electron's size is about three orders of magnitude larger than R, and the scaling dimension (-1) of mass (self-energy), we need to scale up the mass of an electron by at least four orders of magnitudes for it to freely fit into a ball of radius R (and hence be amenable to Schrödinger's equation) giving a proton mass which is at least an order of magnitude too high even if we neglect the EM binding energy. This means that each ECD constituent of a proton must have a size comparable with R, with significant overlaps between different constituents.

Finally, it is conceivable that some unstable hadrons are charged, single particle ECD solutions, not related to the electronic solution via a scaling transformation but constrained by the electron's charge. At present we cannot anticipate whether these are stationary ECD solutions—not necessarily time independent, but with a regular, periodic dependence on time—or chaotic ECD solutions, of the type representing atoms and molecules.

3.1.3 Nuclei

Fundamentally speaking, atomic nuclei are just large ECD composites. Practically speaking, this is not a particularly useful insight, so we shall resort to an intermediate level of abstraction, involving the proton, chosen both for its absolute stability, and because of the role its mass plays in quantizing (albeit only approximately) the atomic masses of all elements, their isotopes included.

The simplest non trivial nucleus is that of a Deuterium atom, and its ECD representation is not qualitatively different from that of a H_2^+ ion: Two protons, plus a negative light particle, frenetically moving (mostly) in between them, thereby countering their mutual Coulomb repulsion—a so-called covalent bond.

The obvious difference between the above two systems is their size, which is about four orders of magnitudes larger for H_2^+. This is apparently the reason why, historically, the appealing (and extremely successful!) picture of a covalent bond was rejected from the outset in early attempts to model atomic nuclei. Nonetheless, by our previous remarks concerning hadrons, it is not that the qualitative picture of an EM covalent bond must fail at such small distances but, rather, that at this smaller scale, Schrödinger's equation fails to consistently describe its statistical properties. Moreover, in this regime, the binding negative particle cannot possibly remain an electron whose size is larger than that of the Deuterium nucleus by three orders of magnitude. Instead, it is some negative ECD particle, contributing little to the overall energy of the system, and only when it escapes the nucleus alone (e.g. in β^- decay) does it eventually assume one of the stable single-particle ECD states, which are charged leptons. When a proton is further released in a nuclear decay, the two could bind to form a metastable neutron and, again, (mainly) the negative particle 'morphs' into a new identity imposed by the different host.

This picture of a neutron—that of a negative particle weakly bound to a proton—is consistent with the neutron's subsequent decay into a proton, an electron, a (anti-)neutrino and possibly a photon, the latter two—we argue in below—being just manifestations of absorption of EM radiation created by the jolting of the electron.

The covalently-bound-protons model of nuclei, further explains the existence of a so-called 'belt/band of stability' in the protons vs. neutrons chart of radioisotopes (which, in our interpretation, is a protons-minus-negative-charges vs. negative-charges chart). The stability of a nucleus with a given number of protons clearly depends on the number of negative charges covalently binding them. Too little of them, and the Coulomb interaction may favour splitting the nucleus. Adding more of them, however, does not increase its binding energy indefinitely. Beyond a certain number, attained at the belt-of-stability, any added binding charge must come at the expense of an existing one (roughly speaking, two such charges cannot both reside in between two protons because of their mutual repulsion). An excess of such negative binding charges allegedly leads to β^- decays. A deficit, in contrast, could have more diverse manifestations. Nuclear fission was already mentioned; An electron captured from the atom clearly gets the nucleus closer to the belt, but also the creation of a charged pair inside the nucleus, followed by the release of the positive particle which, outside the nucleus, morphs into a positron (β^+ decay). Finally, the large ($p \gtrsim 10$) atomic number part of the belt can be nicely fitted by a curve derived from two reasonable assumptions only: 1) The number of negative charges is proportional to that of the protons, minus a term proportional to the surface area of the nucleus (protons on the surface have fewer neighbours) and 2) The volume of a nucleus is proportional to the number of its protons (which is not its atomic number in our model).

3.1.4 (The illusion of...) photons and neutrinos

Photon and neutrino related phenomena embody, perhaps, the most drastic consequence entailed by the inclusion of advanced fields in ECD. To set the stage for their appearance, let us first review the standard classical model of radiation absorption which must obviously be modified.

Suppose, then, that a system decays to a lower energy state, releasing some of its energy (and possibly also linear and angular momentum) content in EM form. The retarded EM pulse carrying this energy subsequently interacts with other systems whose response entails the generation of a secondary retarded field, superposing destructively with the original at large distances, thereby attenuating the pulse's Poynting flux in its original direction. If the response of an absorbing system does not generate a Poynting flux in directions other than that of the original pulse, the process is classified as absorption. Otherwise, it incorporates, to some degree, also scattering. Ultimately, possibly following many scattering process, when the pulse is fully absorbed by matter, its e-m gets reconverted to 'mechanical form', now appearing in the absorbing systems. This complete reconversion means that the (retarded) Poynting flux on a sufficiently large sphere containing the decaying system and the absorbing medium, must vanish.

Two modifications to the above description are mandatory when advanced solutions are included. First, neither retarded nor advanced fields on that large sphere can ever vanish due to the existence of the ZPF. But for the e-m content of the decaying system to remain inside the sphere, it suffices that the time-integral, over the Poynting-flux integral across

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it, should vanish. This, in turn, is just our definition of a system which is in equilibrium with the ZPF, meaning that the absorption of radiation only amounts to a transition of matter inside the sphere, between distinct equi-energetic equilibrium states. Second, ECD systems could also 'undecay'—get energetically exited. A decaying system in our universe is characterized by a sudden imbalance between its retarded and advanced self-fields, favouring the former. In exited systems, that imbalance favours the advanced field. In this case, as well, we postulate that no time-integrated Poynting flux imbalance appears on a sufficiently large sphere containing both the exited system and the system/s where an energy deficit must appear by e-m conservation. Note that, generally speaking, the imbalance between advanced and retarded components, in both decay and excitation scenarios, constitutes a small fraction only of the total self-field of the system. In other words, even in seemingly classical scenarios, e.g. in the transmission of radio waves, what is referred to as the 'retarded field of the antenna' is only a fraction of its full retarded self-field.

If one excludes advanced fields, as historically was the case in CE, then in an excitation scenario, conjectured to apply, e.g., in the ionization of an atom, an electron is suddenly seen ejecting at high speed with no apparent energy source to facilitate such a process. This had led Einstein to hypothesize a neutral massless particle whose collision with the electron resulted in the ionization—a hypothesis which agonized him for the rest of his life.

The symmetry between 'photon production' by a system, viz., transitions favouring the retarded self-field, and 'photon absorption' (advanced field favoured), which is assumed to hold at the microscopic scale, is broken at the macroscopic scale by the arrow-of-time. Photons can be produced by decaying microscopic systems, such as a molecule, but also by a (macroscopic) burning candle, or in Bremsstrahlung, among else. Absorption of photons, in contrast, involves the excitation of microscopic systems only. This asymmetry creeps into the quantum mechanical description of radiation absorption, in which the absorbed (retarded) radiation enters as a classical filed into the wave equation. A typical example is the ionization/excitation of a molecule by a weak external EM pulse, assumed to be generated by some macroscopic source, such as a laser. A standard result of time-dependent perturbation theory, combined with the dipole (long wave-length) approximation and the 'ensemble interpretation' of the wave-function (see section 4 in [5]), imply that the molecule acts as a spectrum analyser for the pulse, with the number of its transitions between states of energy gap ΔE proportional to the spectral density of the pulse at frequency $\Delta E/\hbar$. This result explicitly demonstrates the vanity of expressions such as a 'blue photon'.

The external pulse, of course, is not limited to the relatively low frequencies involved in atomic transitions. But as the frequency is increased towards the γ part of the EM spectrum, there are, in general, fewer systems whose transitions involve the generation of such high frequency secondary retarded waves (needed for absorption of radiation), increasingly involving atomic nuclei. This fact, according to our model, is the reason for the greater penetration power of high frequency pulses, rather than the 'greater energy of high frequency photons'. Similarly, their greater destructive power is explained by the the fact that, in order for the absorbing system to produce a high frequency secondary pulse, its electric current during the transition must, likewise, have high frequency components, implying a more violent response on the part of the absorbing system. (Note that we cannot naively extrapolate the previous results of QM wave equations applied to atomic transitions, to arbitrarily high frequencies, as by our opening remarks for this section, QM wave equations no longer apply to atomic nuclei, hence the need for heuristic arguments).

It is, however, only when photons are 'created' in the decay of a *microscopic* system that the consequences of including advanced fields have their most dramatic effect. According to QM, assumed to correctly capture statistical aspects of ECD solutions, the equilibrium states of bound matter systems are extremely rare compared with the continuous infinity of classical systems (e.g. bound gravitating systems). If we now combine: a) complete absorption; b) e-m conservation; c) severe constraints on ECD equilibrium solutions, we get that the e-m lost in the decay of the microscopic system, must not always appear continuously spread over the interior of the absorbing sphere (so-called soft photons absorption). In some cases, that entire energy deficit of the decaying microscopic system reappears at discrete, possibly remote sites. Moreover, systems directly exposed to the pulse released in the decay of the microscopic system, are obviously more likely to be included in those absorbing 'chosen ones' (consistent with the results of QM, treating the pulse classically) hence the event associated with the emission of photons would lie on the past light cone of the event interpreted as a subsequent absorption thereof.

Our conjectured model of photons-related phenomena can, of course, work only through the 'intimate collaboration' of all the systems inside the sphere. This collaboration is not intermittent, restricted to epochs of photons 'emission and absorption', but rather a permanent one. A local collection of interacting particles, such as the gas molecules filling a particle detector, or even an entire galaxy, must necessarily exhibit such a collaboration for it to remain in equilibrium with the ZPF. This collaboration, however, must not be understood in the sense of information-exchange, with signals running forward and backwards in time (whatever that means). In the block-universe one has to stop thinking in dynamical terms, treating an entire process as single 'space-time structure', constrained by the ECD equations—the basic tenets included in them—and by QM which covers statistical aspects of ECD solutions (see section 4.1 below for more details).

Neutrinos. Neutrinos' alleged 'generation', 'absorption' and 'scattering' (e.g. $n \to p + e^- + \bar{\nu}_e$, $\nu_x + d \to p + p + e^-$ and $\nu_x + e^- \to \nu_x + e^-$ resp.) all involve manifestly radiating systems—jolted charge(s)—and in this regard they are very similar to energetic photons. And like photons, neutrinos seem to propagate at the speed of light, as the SN 1987A supernova clearly shows (unless "God is malicious") in conjunction with artificially produced neutrinos all travelling at light speed to within measurement error. The need for a distinct category (actually three of them) was born out of the necessity to salvage energy and angular momentum conservation in β decay, as no 'photons' were detected which could have done the job. However, ontologically, neutrino related phenomena is indistinguishable from that of photon. The extreme 'penetration depth' of neutrinos is explained by the same argument used above in the case of γ photons: There are allegedly almost no systems whose excitation entails the generation of an EM field, destructively superposing with the incident field (generated in a process associated with the production of a neutrino). In the current

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case, however, the scarcity of such systems is not due to the required extreme frequencies, but probably to very unique, wide band wave forms.

4 ECD and astrophysics

The ZPF is an illusive entity which is practically ignorable on everyday macroscopic scale. In section 3 and in [5], we speculated that only when diving deeply into the atomic and subatomic domains does the ZPF become indispensable in the physical description. In the current section we argue that also by moving in scale in the opposite direction, towards galactic and ultimately cosmological scales, the effects of the ZPF become manifest.

Analysing ECD's consequences to astrophysics requires first that it be consistently fused with general relativity. As advocate in the introduction, this is done by expressing flat spacetime ECD (Maxwell's equations included of course) in an arbitrary coordinate system via the use of a 'metric' $g_{\mu\nu}$. These equations are supplemented by Einstein's field equations

$$\mathcal{R}_{\mu\nu}\left[g_{\mu\nu}\right] - \Lambda g_{\mu\nu} = 8\pi G\left(P_{\mu\nu} - \frac{1}{2}g_{\mu\nu}P^{\lambda}{}_{\lambda}\right)\,, \tag{14}$$

with P the generally covariant e-m tensor, and $\mathcal{R}$ the expression for the Ricci tensor in terms of the metric, $g_{\mu\nu}$, and its derivatives: $\mathcal{R}_{\mu\nu}[g] := \partial_\rho\Gamma^{\rho}{}_{\nu\mu} - \partial_\nu\Gamma^{\rho}{}_{\rho\mu} + \Gamma^{\rho}{}_{\rho\lambda}\Gamma^{\lambda}{}_{\nu\mu} - \Gamma^{\rho}{}_{\nu\lambda}\Gamma^{\lambda}{}_{\rho\mu}$. Equation (14) corresponds to the most general choice of coefficients in (1) for which its l.h.s. is covariantly conserved (by virtue of the second Bianchi identity). This form is mandated by ECD whose e-m tensor, $P_{\mu\nu}$, is by construction covariantly conserved, $\nabla^\mu P_{\mu\nu} = 0$. Note that this is *not* the argument given to this choice by Einstein.[10]

The basic tenets (2)–(4) become their obvious generally covariant extensions. In particular, by the antisymmetry of F, Maxwell's equations simplify to

$$(a)\quad g^{-1/2}\partial_\nu\left(g^{1/2}F^{\nu\mu}\right) = j^\mu \qquad (b)\quad \partial_\lambda F^{\mu\nu} + \partial_\mu F^{\nu\lambda} + \partial_\nu F^{\lambda\mu} = 0\,, \tag{15}$$

while covariant e-m conservation reads

$$g^{-1/2}\partial_\mu\left(g^{1/2}P^{\mu\nu}\right) + \Gamma^{\nu}{}_{\mu\lambda}P^{\mu\lambda} = 0\,, \tag{16}$$

with $g := |\det g_{\mu\nu}|$ and Γ the Christoffel symbol. From (15a) and the antisymmetry of $F^{\mu\nu}$, one gets $\partial_\mu\left(\sqrt{g}j^\mu\right) = 0$ as a consistency condition, generalizing (3).

Using the same construction as in appendix D of [3], one can then show that, if a coordinate system exists for which $g_{\mu\nu}$ is slowly varying over the extent of the particle, then (16) implies that the path of the 'center of the particle', $\gamma^\mu(s)$, (given a clear meaning there) is described by the geodesic equation

$$\ddot{\gamma}^\mu = -\Gamma^{\mu}{}_{\alpha\beta}\dot{\gamma}^\alpha\dot{\gamma}^\beta\,, \tag{17}$$

[10] Einstein's motivation was simply to guarranty $\partial^\mu P_{\mu\nu} = 0$ for the specual case of $g_{\mu\nu} = \eta_{\mu\nu}$. He later [2] realized that, if $g_{\mu\nu}$ plays a role in the structure of matter, then this flat spacetime case needs no longer hold true even in a frame freely falling with a particle, hence the covariant derivative of the l.h.s. of (1) needs not vanish identically.

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with 'dot' standing for the derivative with respect to any parametrization, s, of γ. From (17) we have that $\dot{\gamma}^2 = const$ along γ, from which follows $\mathrm{d}s \propto \sqrt{\mathrm{d}\gamma^2}$.

To define dark-matter, we will also need the following decomposition. Let the exact (modulo a coordinate transformation) metric and ECD e-m tensor in our universe be given by $g_{\mu\nu}$ and $P_{\mu\nu}$ resp. Convolving $P_{\mu\nu}$ with a kernel wide enough for the result to be effectively constant on galactic scales, we denote by $\tilde{P}_{\mu\nu}$ the resulting low-passed/smoothed function, and let $\tilde{g}_{\mu\nu}$ be a solution of (14) for the low-passed source, viz,

$$\mathcal{R}_{\mu\nu}\left[\tilde{g}_{\mu\nu}\right] - \Lambda\tilde{g}_{\mu\nu} = 8\pi G\left(\tilde{P}_{\mu\nu} - \frac{1}{2}\tilde{g}_{\mu\nu}\tilde{g}^{\lambda\rho}\tilde{P}_{\rho\lambda}\right) . \tag{18}$$

The 'tilde tensors' $\tilde{g}$ and $\tilde{P}$ are therefore involved in dynamical changes on a cosmological time scale, and will be studied in section 4.2 dealing with cosmology.

Next, defining the fluctuations, $p_{\mu\nu}$ and $h_{\mu\nu}$ by

$$P_{\mu\nu} = \tilde{P}_{\mu\nu} + p_{\mu\nu} , \quad g_{\mu\nu} = \tilde{g}_{\mu\nu} + h_{\mu\nu} , \tag{19}$$

we substitute $P_{\mu\nu}$ and $g_{\mu\nu}$ from (19) in (14), assume $h_{\mu\nu} \ll \tilde{g}_{\mu\nu}$, and expand $\mathcal{R}_{\mu\nu}[\tilde{g}_{\mu\nu} + h_{\mu\nu}]$ to first order in $h_{\mu\nu}$. Under the assumption of a constant $\tilde{g}_{\mu\nu}$, which will be justified next, we get

$$-\partial_\lambda\partial^\lambda h_{\mu\nu} + \partial_\lambda\partial_\nu h_\mu{}^\lambda + \partial_\lambda\partial_\mu h_\nu{}^\lambda - \partial_\mu\partial_\nu h_\lambda{}^\lambda - \Lambda h_{\mu\nu} + 8\pi G\left(h_{\mu\nu}\tilde{P}_\lambda{}^\lambda + \tilde{g}_{\mu\nu}h^{\rho\lambda}\tilde{P}_{\rho\lambda}\right) = 16\pi G\left(p_{\mu\nu} - \frac{1}{2}\tilde{g}_{\mu\nu}p_\lambda{}^\lambda\right) , \tag{20}$$

where, to first order in $h_{\mu\nu}$, raising of indices can be done with either $g_{\mu\nu}$ or $\tilde{g}_{\mu\nu}$ (note that, (16) imply the conservation of $p_{\mu\nu}$ only to zeroth order in $h_{\mu\nu}$, consistent with the two exchanging e-m). As in our treatment of Maxwell's equations, we assume that no sourceless gravitational waves are propagating in the universe, hence $h_{\mu\nu}$ is entirely due to $p_{\mu\nu}$ (or, $p_{\mu\nu} \equiv 0 \Rightarrow h_{\mu\nu} \equiv 0$, consistent with (18)). Yet, its smallness relative to $\tilde{g}_{\mu\nu}$ is not necessarily due to the smallness of $p_{\mu\nu}$ which, locally (e.g., inside atoms) could be much larger than $\tilde{P}_{\mu\nu}$. Instead, it is due to the smallness of the coupling G. Thus, for $h_{\mu\nu} = O(G)$, the last term on the l.h.s. of (20) is $O(G^2)$ and henceforth neglected. Anticipating the results of section 4.2, the Λ term in (20) is likewise ignored in the current epoch of the universe for its relative smallness.

As a final preparation, the notion of 'physical dimension' must be given a clear meaning. The central theme of section 4.2 is that the result of any measurement is just some real number, not carrying any 'dimension' and that, likewise, ECD is just a set of equations relating different (dimensionless) numbers. The way physical dimensions enter the formalism should become clear through the following example. Suppose that we had an ECD solution representing a standard energy density gauge. The result of measuring p_{00} appearing on the r.h.s. of (20) using this gauge, would be just the ratio between p_{00} appearing in the ECD solution of the measured region, and in that of the gauge. We can then adjust the dimensionless coefficient, G, in (20) so that $p_{\mu\nu}$ becomes the *measured* e-m density, rather than some dimensionless number. When the process is repeated with with standard time, length, and charge gauges, a 'system of units' emerges in which physical constants such as G have a fixed numerical value, which must not be confused with its fundamental ECD value. Under a change of gauges, the 'dimension' of G is then just a prescription for the corresponding transformation of this value.

4.1 ECD and dark matter

Astronomical observations clearly show that for Einstein's field equations to be compatible with observations, some five sixths of the e-m tensor sourcing it must be 'dark' (actually transparent...) in the sense that, its interaction with observable matter and EM radiation, is only through gravity. Such a huge discrepancy could only mean that our understanding is grossly erred in either or both: 1) gravitation; 2) particle physics (being the branch of physics dealing with the nature of matter).

Modified gravity theories, such as MOND [7] and its relativistic extension TeVeS, or the so-called $f(R)$ and scalar-tensor theories, have thus far failed to yield a dark-matter free account of all relevant observations. Modified gravity theories are further way more complicated (and ugly—most would argue) than Einstein's gravity, contain an infinite number of tunable parameters (a function, f, for example, in the case of $f(R)$-gravity) and have merely begun going through the stringent tests already passed by the original. With recent detections of gravitational waves, concurrently with the expected optical signal, a severe new constraint has been added, rendering the prospects of modified gravity based explanations for the dark-matter problem, substantially dimmer.

The more pervasive view is that Einstein's gravity should be kept, and new forms of, yet unknown, exotic matter would resolve the dark-matter problem. This view is claimed to be supported by diverse observations (which are discussed in the sequel) but the truth is that, those observations attest to the existence of dark-matter only insofar as our understanding of ordinary matter is satisfactory. The standard model of particle physics proves to be a reliable tool for calculating certain cross sections in particle collisions. Even with regard to known constituent particles of it—the neutrinos—it failed colossally when first applied to a phenomenon which could not have been tested in accelerators. Its inability to explain what five sixths of the matter 'out there' are, mandates a limited trust in using it outside of its verified, accelerator physics domain. Moreover, there is a growing body of evidence showing that such alleged dark-matter must interact with ordinary matter and with itself in a bizzare (perhaps even self-contradictory) way (see e.g. [11, 6, 10] and additional references therein).

Our proposed solution for the dark-matter problem combines the best of the above two approaches: It leaves Einstein's gravity intact, and yet requires, in principle, no new forms of matter. The missing 'dark e-m tensor' sourcing Einstein's equations is due to the EM energy of the ZPF, hence its 'darkness'.

The analysis which follows relies on equation (20) for the fluctuations around the background. Anticipating the results of section 4.2, dealing with the equations for the background, we shall be using

$$\tilde{g}_{\mu\nu}\left(x^0,\ldots,x^3\right)=a^2(x^0)\eta_{\mu\nu}\,, \tag{21}$$

with $\eta=\operatorname{diag}(1,-1,-1,-1)$ the Minkowski metric, and a some function of x^0 alone which is effectively constant on the time scales relevant to the current section, meaning that its derivatives are ignored. As we shall further see in section 4.2, within the Newtonian approximation, the x coordinates carry the usual metrical meaning of time and space.

As in standard linearized gravity[11] a subset of solutions to (20) (with the last two term on its l.h.s. omitted) relevant to our case satisfies the simpler equation

$$-a^{-2}\Box h_{\mu\nu}=16\pi G\left(p_{\nu\mu}-\frac{1}{2}\eta_{\nu\mu}p_{\rho\sigma}\eta^{\sigma\rho}\right)\,. \tag{22}$$

As p still contains the fluctuations in the ZPF and the internals of atoms and molecules, both irrelevant to the dynamics of galaxies, we utilize the linearity of (22) and 'low-pass' it, viz., convolve it with a space-time kernel much wider than typical atomic size/time. Retaining the symbol for the low-passed p, the resulting r.h.s. should be separately treated for matter and radiation dominated regions. Starting with the former, and focusing on a single static particle with its associated $p^{(a)}$ (see section 2.2 for a reminder), the absence of bulk motion and the time-independence of the particle's self-energy, readily translate into $p^{(a)}_{ij}=p^{(a)}_{i0}=0$ (see [3] eq. (99); For a moving particle, one simply boosts the static result). The temporal part of the l.h.s. of (22) is obviously negligible for a slowly varying p. Newtonian gravity then follows by defining the normalized fluctuation, $\Phi:=a^{-2}h_{00}/2$, yielding Poisson's equation for the Newtonian potential Φ

$$\nabla^2\Phi=8\pi G\left(p_{00}-\frac{1}{2}p^{\lambda}{}_{\lambda}\right)\,. \tag{23}$$

In this approximation, the r.h.s. of (23) is the standard Newtonian $4\pi Gp_{00}$, while the geodesic equation (17) reduces to Newton's equation

$$\ddot{\boldsymbol{\gamma}}=-\boldsymbol{\nabla}\Phi(\boldsymbol{\gamma}) \tag{24}$$

for non-relativistic motion, with 'dot' being derivative with respect to x^0.

The above analysis shows that, *sourcing linearized gravity are the fluctuations, p, relative to the universal background, $\tilde{P}$*, rather than the full e-m tensor, P, as it appears in the literature (e.g. [9] p.253). This distinction becomes critical in the case of a non vanishing Λ.

In regions void of matter, where $\sum_a T^{(a)}=0$ and the ZPF dominates the r.h.s. of (22), the tracelessness of the canonical tensor Θ implies that the r.h.s. of (23) becomes $8\pi Gp_{00}$, viz., twice the value expected from naive mass-energy conversion. Unlike in the case of matter, however, we cannot simply neglect p_{ij} and p_{i0}, sourcing the corresponding components of h. Nevertheless, for non-relativistic motion, (24) is still a valid approximation and weak gravitational lensing calculations likewise involve only Φ. Moreover, we assume

[11] See, e.g., [9] section 10.1, but note the different sign convention for the metric.

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that the low-passed p in those regions is changing only on cosmological time scales hence the temporal part of the l.h.s. of (22) is still negligible.

No attempt is made in this short paper to fully cover the astronomical observations concerning dark-matter, which have occupied telescopes around the globe for several decades. Instead, we shall demonstrate how the more universal aspects of this huge body of knowledge follow inevitably from generally covariant ECD.

4.1.1 Rotation curves of spiral galaxies

The best laboratories for testing dark-matter theories are spiral (or disk) galaxies. These are the only astronomical objects in which the local *acceleration vector* of individual particles can be reliably inferred from the projection of their velocity on the line-of-sight, as deduced from the Doppler shift of their emitted spectral lines.

Masses in the disk's plane move approximately in circular motion around the galaxy's center, with a velocity, $V(R)$, depending on the distance, R, from the galactic center. A reliable estimation of the visible mass distribution in the disk, generally depending exponentially on R, allows one to infer a class of dark-matter distributions whose inclusion would salvage Einstein's gravity. One then finds that, in most galaxies, a *spherically* symmetric dark-matter distribution of the form

$$\rho_d(r) = \rho_0 \left[1 + \left(\frac{r}{r_c} \right)^2 \right]^{-1} \tag{25}$$

known as the 'pseudo-isothermal halo', with ρ_0 and r_c galaxy-specific tunable parameters, does a decent job in explaining the observed 'rotation curve' $V(R)$.

Increasing the number of tunable parameters in a family of dark-matter halos, naturally leads to a better fit with observations, but besides lacking real physical motivation, such halos almost never explain the fine details of the rotation curve at places where dark-matter supposedly abounds (MOND does a much better job on that). In what follows we shall show how the dynamics resulting from the pseudo-isothermal halo (25) emerges naturally only as as a coarse grained approximation, consistent with the existence of finer details in the rotation curve.

According to our proposal, rather than inventing new forms of matter to explain the apparent deficit on the r.h.s. of (23), one has to take into account the effect which ordinary matter has on its surrounding ZPF. Looking at a sufficiently isolated galaxy, one can safely attribute the EM part of p_{00} to the radiative part of self-fields adjunct to the galaxy's constituent particles (the Coulomb part, by our previous remarks, appears in p_{00} of matter). We shall use the dipole term only to represent this radiation, but this is just to ease the presentation, with higher order multipoles adding nothing new to the discussion. In this approximation we have

$$\boldsymbol{B}^{(a)}_{\substack{\text{ret}\\ \text{adv}}}(t, \boldsymbol{x}) = \frac{\boldsymbol{n}^{(a)} \times \ddot{\boldsymbol{p}}^{(a)} \left(t \mp \left| \boldsymbol{x} - \boldsymbol{x}^{(a)} \right| \right)}{\left| \boldsymbol{x} - \boldsymbol{x}^{(a)} \right|}\,, \qquad \boldsymbol{E}^{(a)} = \boldsymbol{B}^{(a)} \times \boldsymbol{n}^{(a)}\,. \tag{26}$$

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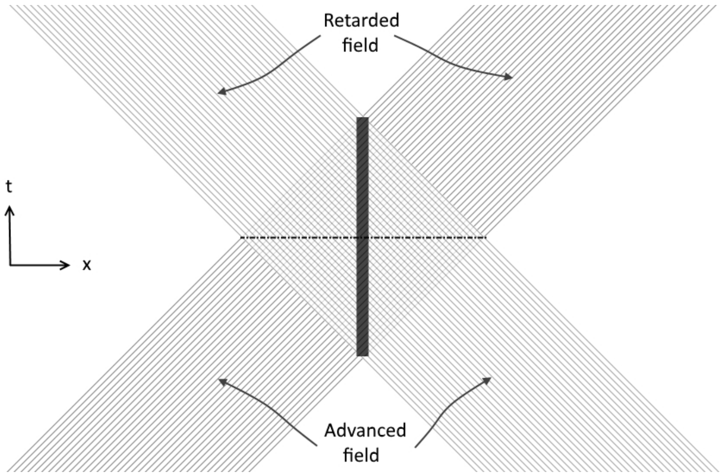

Figure 2: Thick vertical line represents a galaxy in a $1+1$ world, existing for a finite time. Dashed horizontal line is the validity domain of expression (28).

Above, $a = 1 \ldots N$ is a label carried by each particle whose associated magnetic and electric fields are $\boldsymbol{B}^{(a)}$ and $\boldsymbol{E}^{(a)}$; $\boldsymbol{x}^{(a)}$, its c.o.m., $\boldsymbol{n}^{(a)} = \left(\boldsymbol{x} - \boldsymbol{x}^{(a)}\right) / \left|\boldsymbol{x} - \boldsymbol{x}^{(a)}\right|$ a unit vector pointing from it at the point of interest, $\boldsymbol{x}$. The particle's dipole moment is $\boldsymbol{p}^{(a)}(t') = \int \mathrm{d}^3 y \boldsymbol{y} \varrho^{(a)}(t', \boldsymbol{y})$ where $\varrho^{(a)}$ is its charge density, and 'dot' stands for a time derivative.

The EM energy density $p_{00} = \Theta_{00}(0, \boldsymbol{x}) = \frac{1}{2}\left(\boldsymbol{E}_{\text{total}}^2 + \boldsymbol{B}_{\text{total}}^2\right)$ involves both a double summation over the particle labels and a separate count for their advanced and retarded contributions. As the particles are assumed to be in equilibrium, those two contributions are equally weighted, reflecting $\langle \alpha_{\text{ret}} \rangle = \langle \alpha_{\text{adv}} \rangle = \frac{1}{2}$ in (10). The magnetic contribution to the energy density thus reads

$$\frac{1}{4} \sum_{a,b} \sum_{\epsilon, \epsilon' = 1, -1} \frac{\boldsymbol{n}^{(a)} \times \ddot{\boldsymbol{p}}^{(a)}\left(\epsilon \left|\boldsymbol{x} - \boldsymbol{x}^{(a)}\right|\right) \cdot \boldsymbol{n}^{(b)} \times \ddot{\boldsymbol{p}}^{(b)}\left(\epsilon' \left|\boldsymbol{x} - \boldsymbol{x}^{(b)}\right|\right)}{\left|\boldsymbol{x} - \boldsymbol{x}^{(a)}\right| \left|\boldsymbol{x} - \boldsymbol{x}^{(b)}\right|}, \tag{27}$$

and similarly for the electric contribution.

For a galaxy whose center coincides with the origin, and for $\boldsymbol{x} \gg \boldsymbol{x}^{(a)}, \boldsymbol{x}^{(b)}$, viz., in regions practically empty of matter, we can use the following approximations in (27). In the denominator, $\left|\boldsymbol{x} - \boldsymbol{x}^{(a)}\right| \simeq \left|\boldsymbol{x} - \boldsymbol{x}^{(b)}\right| \simeq |\boldsymbol{x}|$, and in the numerator, $\boldsymbol{n}^{(a)} \simeq \boldsymbol{n}^{(b)} \equiv \hat{\boldsymbol{x}}$. If we further assume that the dipoles are stationary in the statistical sense (but not necessarily independent; see next), an asymptotic form of (27) respecting the symmetries of the dipoles' spatial distribution, must takes the simple, time-independent form

$$p_{00}(\boldsymbol{x}) \sim \frac{f(\hat{\boldsymbol{x}} \cdot \hat{\boldsymbol{a}})}{|\boldsymbol{x}|^2}, \tag{28}$$

for some symmetric function, f, with $\hat{\boldsymbol{a}}$ a unit vector perpendicular to the galactic plane. Note that the non integrability of (28) at infinity is an artefact of assuming an eternally existing galaxy in an infinite, flat universe otherwise void of matter (see figure 2) which is

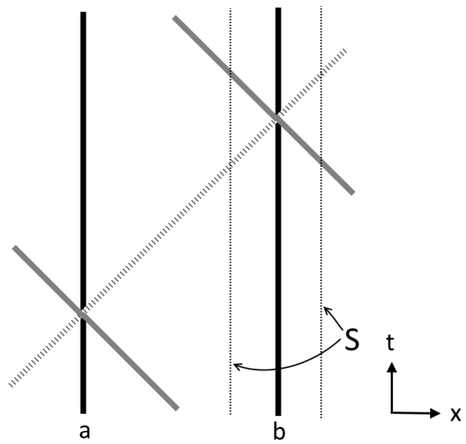

Figure 3: Mutual absorption between two particles in equilibrium with the ZPF. Dashed ray represents the locus of destructive interference. Note that in 3+1 spacetime, the degree of interference is minimal near each dipole, transversely extending beyond the ray, and its overall effect decreases with increasing inter-particle separation.

not in accord with the ECD cosmological model presented in section 4.2 below. Solving (23) for such a symmetric energy density, one can easily show that, up to an additive irrelevant constant, for either $\hat{\boldsymbol{x}} \parallel \hat{\boldsymbol{a}}$ or $\hat{\boldsymbol{x}} \perp \hat{\boldsymbol{a}}$, Φ has an asymptotic, large $|\boldsymbol{x}|$ form

$$\Phi\left(\boldsymbol{x}\right) \sim GF(\hat{\boldsymbol{x}}) \ln |\boldsymbol{x}| \,, \qquad \hat{\boldsymbol{x}} \parallel \hat{\boldsymbol{a}} \quad \text{or} \quad \hat{\boldsymbol{x}} \perp \hat{\boldsymbol{a}} \,. \tag{29}$$

By symmetry argument alone, the gradient of Φ in those two special directions must point in the corresponding direction of $\hat{\boldsymbol{x}}$.

Moving next to matter rich regions in the disk, the EM energy density becomes locally coordinated with that of matter: According to (27), associated with each 'diagonal contribution' to the sum, viz., $\text{a} = \text{b} \cap \epsilon = \epsilon'$, is an EM halo whose energy density drops as $\left|\boldsymbol{x} - \boldsymbol{x}^{(a)}\right|^{-2}$ away from dipole (a), contributing to the energy content of a ball of radius r centered at $\boldsymbol{x}^{(a)}$, an amount which is $\propto r$. Ignoring the off-diagonal terms in (27), each dipole thus effectively gains a mass which would have been infinite for a completely isolated dipole. This catastrophe is avoided by considering also the off-diagonal terms, $\text{a} \neq \text{b} \cap \epsilon = -\epsilon'$, representing certain destructive interference effects between different dipoles. In sparse regions, interference is insignificant in the dipole's vicinity, implying a larger effective r than in dense regions, where it begins closer to $\boldsymbol{x}^{(a)}$.

The interference effect we refer to above, is similar to the classical process of absorption discussed in section 3.1.4, dealing with photons, but with one critical difference: There, the destructive interference between the incident retarded field and the secondary retarded field,

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generated by the absorbing system, entails the excitation of that system in order to respect e-m conservation. In the current case, in contrast, the incident retarded field superposes destructively also with the advanced field of the absorbing system (see figure 3). This destructive interference guaranties that the Poynting flux across a sphere, S, containing the absorbing system (or, as it should more appropriately be called in this case: the reacting system), vanishes, respecting its equilibrium with the ZPF. Reversing the roles of advanced and retarded fields, the advanced field of system b is likewise absorbed by system a. At the level of equilibrium with the ZPF, the arrow-of-time is inconsequential.

All this adds to the following picture which is consistent with observations. Moving in the plane of the galaxy away from its center, one sees two opposing trends: On the one hand, the decreasing particle density should reduce the local EM energy density, but on the other hand, such a decrease reduces the suppression due to interference, increasing the effective r of each dipole. It follows that the *ratio* of dark-to-ordinary matter densities, increases with decreasing density. This explains why, despite an exponential decrease in the surface density of ordinary matter as a function of R, common to most spiral galaxies, the observed dark-matter density is approximately constant in matter rich regions, as in (25) for $r < r_c$. We shall refer to the local matter ratio, dark+ordinary/ordinary, as the local *enhancement factor* of ordinary matter.

In low surface brightness (LSB) galaxies, e.g. fig. 4, interference is small due to their low matter density, and the enhancement factor should be large already at the center of the galaxy, explaining why such galaxies appear to be dark-matter dominated, as well as the relatively extended halo core radius r_c. High surface brightness galaxies (HSB), in contrast, have a very small enhancement factor in most of their visible disk and, therefore, almost no dark-matter is required to explain their rotation curve for small R.

An interesting point to note with regard to the radius at which 'dark-matter kicks in', viz., the enhancement factor becomes significantly greater than one, is that the acceleration of orbiting matter there, by then a decreasing function of R, reaches some universal value a_0, known as the MOND acceleration. To show how such a universal acceleration follows from our model, one only needs to assume that disk galaxies all have an exponential surface density of the form

$$\Sigma(R) = \Sigma_0 e^{-R/R_d}, \tag{30}$$

and that dark-matter kicks in when the surface density drops below a universal critical value $\Sigma_c := a_0/(2\pi G)$. The first assumption is confirmed by observations; That, the point at which dark-matter kicks in, is determined by the local density, follows from the preceding discussion. It can then be shown by a straightforward calculation that, the acceleration at that point of critical density, takes the form $a = 2\pi G \Sigma_c \mathcal{F}(\Sigma_0/\Sigma_c) = a_0 \mathcal{F}(\Sigma_0/\Sigma_c)$ for a slowly varying function $\mathcal{F}(x)$. Further recalling Freeman's law, according to which the central surface brightness is the same in all HSB galaxies, and that the mass-to-light ratio in all of them is on the same order of magnitude, in conjunction with $\mathcal{F}(x) \approx 1$ for the relevant range $2 < x < 12$, we get $a \approx a_0$. The MOND phenomenology, attributing a fundamental significance to a_0, is a mere peculiarity of spiral galaxies by our analysis.

Whereas near the center of HSB galaxies, the exponential decrease in the surface density is

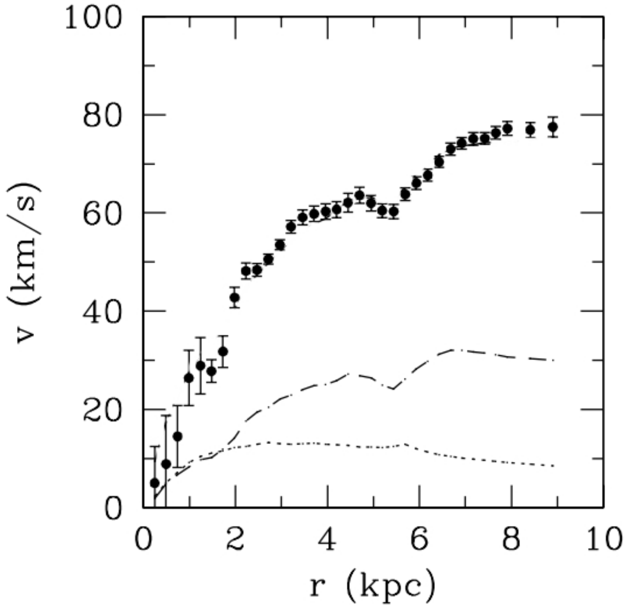

Figure 4: The rotation curve $V(R)$ (bared spots) of LSB galaxy NGC 1560 (from [8]). Dotted and dashed lines are the rotation curves calculated separately for stars and gas resp. The feature around 5.5 kpc is consistent with a dark-matter density which is almost locally equal to the corresponding matter density, amounting to a local enhancement factor of about 2 which is basically constant over the range of the feature. In addition to the local EM enhancement of ordinary matter—mostly gas in this case—the cumulative contribution of EM dark-matter at $R < 5.5$ kpc lifts the rotation curve to its observed hight.

countered by a comparable increase in the local enhancement factor, this balance cannot persist to an arbitrarily large R. The suppressing effect of interference, involving inter-particle interaction, obviously depends non linearly on the density (in the simplest approximation it would be quadratic in the density). As the density drops, therefore, the decrease in interference becomes more moderate compared with the constant decrease in the density itself. This means that the local enhancement factor in sparse regions of a galaxy (large R) is much less sensitive to the density than near the galactic center. This phenomenon can explain the fine details of the rotation curve, completely missing from halos of the form (25) (see figure 4). And yet, to predict a full rotation curve (equivalently, a dark-matter density profile) from a given ordinary matter distribution, as MOND does rather successfully, one should go beyond the local enhancement mechanism, treating also the non-local part—the part of the self-field which escapes the local neighbourhood of a dipole, responsible among else for the asymptotic flatness of the rotation curve. This task will be attempted elsewhere, as it requires a much more detailed model. However, a key point to note in this regard is that, the strength of an individual dipole, is a free parameter (another one is some interference coefficient). More accurately, the validity of the cosmological model derived from ECD (see section 4.2 below) is basically independent of that strength. One obvious implication of this is that, deriving the observed value of a_0, is a trivial task.

Moving further away from the center of a galaxy, the rotation curve eventually flattens,

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as follows from the asymptotic logarithmic form, (29), of the potential (the contribution of visible matter to the potential dies-off faster, as R^{-1}). The coefficient of that potential correlates rather well with a_0 and the total visible mass, M, of the galaxy, and reads $\sqrt{GMa_0}$. This relation, also known as the as the Baryonic Tully-Fisher relation (BTFR), follows from our model simply on dimensional grounds. As Φ is a solution of (23), the F appearing in (29), denoted $F_\perp$ for $\hat{\boldsymbol{x}} \perp \hat{\boldsymbol{a}}$, must have dimension $[F_\perp] = m/l$. We further want it to monotonically increase with M—the number of radiating dipoles—but in a concave manner, as more particles also imply greater absorption. Finally, $F_\perp$ should monotonically increase also with Σ_c. A larger Σ_c implies smaller interference, meaning that more radiation escapes the galaxy (note that Σ_c already incorporates the details of any reasonable interference model). The only such option up to a dimensionless coefficient is $F_\perp = \sqrt{M\Sigma_c}$, rendering the full coefficient of the logarithm $\sqrt{G^2M\Sigma_c} = \sqrt{GMa_0}$ which is the BTFR. For the class (30) of density profiles, the dimensionless coefficient can only be a function of the ratio Σ_c/Σ_0 which, by our previous remarks, does not vary much between different HSB galaxies.

Summarizing, with Σ_c and the average strength of individual dipoles being tunable parameters, any reasonable interference model would reproduce: 1) The BTFR; 2) The MOND acceleration, a_0, at which dark-matter kicks in; 3) A MOND-like dependence of the fine details in the rotation curve, on ordinary mass distribution.

4.1.2 Clusters of galaxies

When dealing with the dynamics of clusters of galaxies, the asymptotic potential (29), must be interpreted with more care. For example, even if we assume a spherically symmetric asymptotic potential $\sqrt{GMa_0}\ln r$, implying a derived radial force field, Newton's law of action and reaction would not apply to two galaxies of distinct masses. Yet worse, the asymptotic EM dark-matter density (28) is typically not spherically symmetric, being strongest in the direction of greatest transparency which, for disk galaxies, is the normal to the galactic plane. The associated force field of the asymptotic potential is therefore, likewise, non spherically symmetric and non radial. In both cases, nonetheless, energy-momentum conservation is salvaged by the fact that each galaxy carries with it also an EM halo.

While it is beyond the scope of the current paper to derive an expression for the velocity dispersion in a cluster, given each galaxy's visible mass distribution, a comparison with the corresponding MOND result gives an encouraging indication. In a MOND N-body simulation of a cluster, each galaxy is treated as a point, exerting a radial, spherically symmetric force on the rest. By the BTFR, whenever galaxy **a** lies in the plane of galaxy **b**, the acceleration experienced by **a**, according to MOND, coincides with ours. In the latter model, however, such an atypical orientation of **b**, represents the *weakest* possible influence **b** can have on **a** for a given separation distance (again, galaxies are least transparent when viewed from their plane). And, indeed, MOND systematically predicts intergalactic interaction which, while rendering redundant most (conventional) dark-matter, is still too weak by a factor $2 \sim 10$.

An additional probe of dark-matter in clusters is based on weak gravitational lensing of background galaxies. According to our model, the contributions of different galaxies to the local EM field can be safely assumed to be incoherent, meaning that the EM dark-matter associated with each can be added. Given the asymptotic form (28), and the large intergalactic void compared with the optical size of typical galaxies in a cluster, it is clear that the combined mass density of the cluster, though correlated with the density of galaxies when averaged on sufficiently large regions, is entirely dominated by EM dark energy, by a factor which can easily reach 10 or even 100, depending on the location in the cluster.

In our analysis of spiral's rotation curves in section 4.1.1, we completely ignored the composition of the galaxy, i.e, whether it is gas or star dominated, age of stars etc. This property, consistent with observations [6], will ultimately have to be incorporated into a more detailed model, but seems compatible[12] with our proposed absorption mechanism, and with the relatively small optical depth in the galactic plane. However, this composition independence is not expected to carry to an arbitrary aggregate of matter. Consider, for example, what would happen to the dark-matter content of a cluster, if each galaxy in it were to vaporize, evenly distributing its mass across the entire cluster in a gaseous form. On the one hand, we would have some local EM enhancement of the gaseous mass density by a factor $2 \sim 4$, as in a LSB galaxy, but on the other hand, we would lose to absorption most of the asymptotic tail of (28) attached to individual galaxies in the original solid cluster (recall the divergent nature of that tail). As intergalactic interference effects are negligible in typical clusters due to their sparsity, it is clear that for a cluster of a sufficiently low galactic density, the dark-matter content of its gaseous counterpart would be much smaller in comparison.

The much greater dark-matter content in a cluster of isolated galaxies, compared with a cloud of gas with a similar (ordinary) mass, is not easily amenable to direct tests, as clusters generally contain both gas and galaxies. There is, however, a notable exception to this rule, known as the 'Bullet Cluster' (1E 0657-558), whose collision with another cluster had stripped it from its gas content, leaving a cluster virtually composed of galaxies only. Although the mass of the gas left behind greatly exceeds that of the bare cluster, the total mass distribution in the region of collision, as inferred from weak gravitational lensing, is dominated by dark-matter whose distribution correlates well with the distribution of galaxies alone. This observation is but a private case of a general prediction of ECD, following from the previous discussion: The percentage of dark-matter in a cluster should be anti-correlated with its gas content.

4.2 ECD and cosmology

Our analysis of (generally covariant-) ECD's consequences to cosmology will involve the tilde quantities $\tilde{g}$ and $\tilde{P}$ rather than the fluctuations, h and p, used in section 4.1. Taking into account the large scale homogeneity of space, it is an easy exercise to show that a coordinate system must exist in which the corresponding metric takes the form

$$\tilde{g}_{00} = u^2(x^0)\,, \quad \tilde{g}_{0i} = 0\,, \quad \tilde{g}_{ij} = -w^2(x^0)\delta_{ij}\,, \tag{31}$$

[12] Since our proposed explanation of dark-matter is entirely of statistical nature, it is plausible that, the said composition independence, cannot be derived from deeper principles. This is precisely our approach in [5] towards other statistical effects associated with the ZPF, involving QM phenomena.

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for some functions u and w. More accurately, $\tilde{g}_{ij}$ in (31) could have, in spatially curved spaces ($k = \pm 1$ in the literature), a somewhat more general, yet still maximally symmetric form, involving also x^i, but for the flat space scenario ($k = 0$) on which we focus, that spatial dependence degenerates. Defining the so-called 'cosmological time', t,

$$t = \int^{x^0} u(\alpha)\mathrm{d}\alpha \, .$$

the metric (31) becomes

$$\tilde{g}_{tt} = 1 \, , \quad \tilde{g}_{ti} = 0 \, , \quad \tilde{g}_{ij} = -\bar{w}^2(t)\delta_{ij} \, ; \qquad \bar{w}(t) := w\left(x^0(t)\right) \, . \tag{32}$$

Thus far our presentation is in agreement with most texts on GR, with the form (32) of the (flat-space) metric being just a matter of definition. But from here on, the standard analysis proceeds in a way which turns out incompatible with ECD. In the standard approach, relying heavily on the mathematical similarity between GR and differential geometry, $g_{\mu\nu}$, or rather the coordinate invariant interval $\mathrm{d}s := \left(g_{\mu\nu}\mathrm{d}x^\mu \mathrm{d}x^\nu\right)^{1/2}$ has a selective metrical role, involving space/time measurements. In particular, the interval between two points on the world line of a comoving physical clock, must be proportional to the corresponding time difference shown by the clock. It then follows that, for local null geodesics to have a constant measured speed-of-light $c = 1$, any local length measurement, must forever be proportional to the 'proper-distance' derived from the metric (32)

$$\delta\ell = \beta\sqrt{-\tilde{g}_{ij}\delta x^i \delta x^j} = \beta\bar{w}(t)\|\delta\boldsymbol{x}\| \, , \tag{33}$$

with β depending on the choice of units (usually taken to equal 1).

The above result is a direct consequence of a) Minkowskian physics locally appllying in a freely falling frame, and b) A standard length/time gauge spans a fixed coordinate interval. Point (a) is just our 'slim' version of the equivalence principle (footnote 3 in the introduction) but ECD's scale covariance prohibits assigning a priori metrical meaning to coordinate intervals[13], invalidating point (b). Instead of (33), we must therefore use directly the *definition* of a measurement: *The result of any measurement is some dimensionless number extracted solely from the e-m tensor*[14]. As we shall see, a constant β throughout spacetime, turns out to be incompatible with ECD's realization of this definition. Note also that, by 'relieving $g_{\mu\nu}$ from its metrical duty', the conceptual difficulties with quantum gravity disappear; space and time no longer have any meaning other than that related to the readings of clocks and other gauges. Quantum gravity then becomes just the statistical description of the generally covariant ECD block-universe (see [5] for the flat spacetime case).

[13]Recalling from the introduction that the symmetric matrix $g_{\mu\nu}$ emerges simply as a consequence of changing coordinates, we ascribe no metric meaning to it; the term 'metric' is therefore a misnomer in our approach

[14]For example, a standard length gauge is represented by some compact region in space, occupied by a relatively higher energy density. The length of an object in standard length units, likewise occupying some compact region in space, is just the *number* of standard gauges exactly fitting the object. Similarly, the object's luminosity is just just the *number* of standard candles leading to the same 'displacement of the needle' in a bolometer which, in turn, is defined as some device whose needle's displacement is proportional to the number of candles.

4.2.1 The Friedman model for an ECD universe

The overall framework used in this section is the so-called Friedman model, i.e., the coarse metric has the Robertson-Wallker (RW) form, (32), representing a maximally symmetric space at any given time, and the coarse grained source $\tilde{P}$, is likewise maximally symmetric, representing the observed large-scale isotropy of matter distribution and the cosmological principle (we are not at a privileged position in space hence isotropy implies homogeneity). To ease the calculations we, again, redefine the time coordinate in (32) so that the RW metric takes the more symmetric form (21), rewritten here

$$\tilde{g}_{\mu\nu}\left(x^0,\ldots,x^3\right) = a^2(x^0)\eta_{\mu\nu}\,.$$

The time x^0 in (21), denoted also by τ, is known as the *conformal time.*

The tensor $\tilde{P}$ incorporates two distinct forms of contributions: EM one, due to the ZPF, and one from matter, i.e., from regions of non vanishing mechanical e-m T. The three-tensor $\tilde{P}^{ij}$ must be invariant under rotations so as to respect the isotropy of space. For the same reason, the vector, $\tilde{P}^{0i} = \tilde{P}^{i0}$, must vanish, leaving us with

$$\tilde{P}^{00} = \rho(\tau)\,, \quad \tilde{P}^{0i} = 0\,, \quad \tilde{P}^{ij} = -\eta^{ij}\mathsf{p}(\tau)\,, \tag{34}$$

with ρ and p arbitrary functions of time alone. In the case of the ZPF, the tracelessness of $\Theta^{\mu\nu}$, and $\Theta^{00} \geq 0$ necessitate

$$\mathsf{p}_{\text{ZPF}} = \rho_{\text{ZPF}}/3\,, \quad \rho_{\text{ZPF}} \geq 0\,. \tag{35}$$

Inside matter itself, we have also a contribution from T, spoiling the tracelessness of $\tilde{P}$. Now, in the context of dark-matter, we have previously argued that, for slowly moving particles,

$$\mathsf{p}_{\text{matter}} \approx 0\,. \tag{36}$$

This result, not relying on the explicit from of T, is equivalent to the statement that, for a particle to remain 'the same particle' and, in particular, maintain a fixed four-momentum when freely moving, its internal Poincare stress, $T^{(a)}_{i\mu}$, must locally cancel with the EM stress, $\Theta_{i\mu}$, together making its total stress $P^{(a)}_{i\mu}$. Implicit in (36), therefore, is the condition that the particle be in equilibrium with the ZPF. Moreover, the positivity of T^{00} is guaranteed only for such mass conserving particles. In the early universe, we shall later argue, this is no longer the case. The ρ and p in matter dominated regions must then be calculated separately for the EM component of $P^{(a)}$, and for $T^{(a)}$, with a result which, in general, could be different from (36).

A mixture of ZPF and ordinary, non relativistic matter, with a ratio $\epsilon := \rho_{\text{matter}}/\rho_{\text{ZPF}}$, is therefore represented by an equation-of-state for $\tilde{P}$ (34)

$$\mathsf{p}_{\text{total}} = \frac{\rho_{\text{total}}}{3(1+\epsilon)}\,. \tag{37}$$

To leading order in h, covariant e-m conservation (16) implies the same equation for $\tilde{P}$:

$$g^{-1/2}\partial_\mu \left(g^{1/2}\tilde{P}^{\mu\nu} \right) + \tilde{\Gamma}^\nu{}_{\mu\lambda}\tilde{P}^{\mu\lambda} = 0$$

with $g^{1/2} := |\det \tilde{g}_{\mu\nu}|^{1/2} = a^4$ and $\tilde{\Gamma}$ the Christoffel symbol derived from the RW metric (21). This gives

$$\frac{\mathrm{d}}{\mathrm{d}\tau}\left(a^4\rho\right) = -a^3\dot{a}\left(\rho + 3\mathsf{p}\right) . \tag{38}$$

Recalling from section 4.1 that the dark-matter content of our universe exceeds that of visible matter by a factor of ~ 5, and that it is due to inhomogeneities in the ZPF only, we can safely assume $\epsilon \ll 1$ in the current epoch of the universe. Unless otherwise stated, we shall therefore assume $\epsilon = 0$, as the inclusion of any other reasonable estimate can be shown to have a marginal effect only on our results. For a constant ϵ, (38) translates into

$$\frac{\mathrm{d}}{\mathrm{d}a}\left(a^4\bar{\rho}\right) = -a^3\left(\bar{\rho} + 3\bar{\mathsf{p}}\right) , \tag{39}$$

with $\bar{\rho}(a) := \rho(\tau(a))$ and $\bar{\mathsf{p}}(a) := \mathsf{p}(\tau(a))$, which for $\epsilon = 0$ readily gives

$$\bar{\rho} = C'a^{-6}\,, \tag{40}$$

for some constant C'. Equations (18) for $\tilde{g}$ reduce for $\epsilon = 0$ to a single o.d.e. for $a(\tau)$,

$$\dot{a}^2 = -\frac{\Lambda}{3}a^4 + \frac{8\pi G}{3}a^6\bar{\rho}\,. \tag{41}$$

Substituting (40) into (41) we get the o.d.e.

$$\dot{a}^2 = -\frac{\Lambda}{3}a^4 + \frac{C}{3}\,, \qquad C = 8\pi G C'\,. \tag{42}$$

We shall see that, in order to conform with observations, solutions of (42) would need to satisfy $\dot{a}(\tau) < 0$!!!

4.2.2 The redshift of distant objects

The matter in the universe, albeit contributing negligibly to the coarse grained e-m $\tilde{P}$, is indispensable in two complementary senses. First, without matter there is no ZPF; Matter and the ZPF are just different facets of the same physical entity, and the smallness of ϵ merely reflects the large void between matter in the universe, where the ZPF can attain its dominance. Second, without matter, there are no astronomical objects and no equipment to observe them.

We shall represent (the centers of) particles in the universe by a collection of world-lines, $\gamma(s)$, which is compatible with the time independent homogeneity of $\tilde{P}$. Such world-lines must be those of *comoving particles*, viz., have the form $\gamma^i = \text{const}$, so as to respect the above compatibility condition at any time. By virtue of the geodesic equation (17), and $\Gamma^i{}_{00}$

derived from the RW metric (21) vanishing, those are indeed the world-lines of 'freely falling' particles. Mach's vague principle is thereby given a concrete meaning, as the world-line of a fixed spatial coordinates triplet, belonging to a local frame which is rotating relative to the local comoving frame, will no longer solve the geodesic equation (17).

A simplifying feature of a generally covariant generalization of a (flat) scale covariant theory, such as Maxwell's equations (15) or generally covariant ECD, is that its equations in a background $g_{\mu\nu} \equiv a^2\eta_{\mu\nu}$ ($a \equiv const$), are independent of the 'scale factor' a, viz., are just the flat spacetime equations. On time scales over which a in (21) is effectively constant, flat spacetime ECD therefore locally applies in the x coordinates. We therefore get a specific instance of our 'slim' equivalence principle, without introducing any new postulate (By 'slim' we obviously refer to ECD's scale covariance, which excludes assigning any absolute metrical significance to those coordinates).

Next, we wish to investigate the observational consequences of a gradual change in the intensity of the ZPF over cosmological time scales—a consequence of (40) and (42). The main challenge we face is in the need to give meaning to a comparison of properties of matter at two distinct conformal times, without resorting to the 'universal length gauge', derived from the metric at every point in the universe. For reasons which will transpire shortly, we shall first obtain a global solution of the sourceless (curved spacetime) Maxwell's equation (15). Plugging $g = a^8(\tau)$ and $F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu$ into (15), with the plane-wave ansatz

$$A^\mu := S(\tau; k_0)\chi^\mu \exp ik_\nu x^\nu\,, \quad k^\mu k_\mu = 0\,, \quad \chi^\mu k_\mu = 0\,,$$

we get an o.d.e. for $S(\tau)$,

$$\frac{2\dot{a}}{a} = -\frac{\ddot{S} - 2i\dot{S}k_0}{\dot{S} - iSk_0}\,. \tag{43}$$

For large $|k_0|$, solutions of (43) simplify to the k_0-independent form

$$k_0 \gg \frac{\dot{a}}{a} \quad \Rightarrow \quad S(\tau) = S(\tau_0)\left(\frac{a(\tau)}{a(\tau_0)}\right)^{-1}\,, \tag{44}$$

By linearity, any wave-packet solution of (15) containing sufficiently high frequencies, undergoes a simple amplitude stretching given by (44).

Returning to our problem, of determining the consequences of a time varying ZPF, we shall focus on a primary observable in cosmology, known as the *luminosity distance* of an isotropically radiating astronomical object,

$$d_{\text{L}} := \sqrt{\frac{L}{4\pi\mathcal{F}}}\quad. \tag{45}$$

Above, $\mathcal{F}$ is the measured energy-flux (or bolometric luminosity), as determined by an astronomer with (fixed) coordinates $\boldsymbol{x}_{\text{A}}$ (the spatial part x_{A}) at conformal-time $x^0_{\text{A}} \equiv \tau_{\text{A}}$, and L is the object's total power, or luminosity, as would have been determined by the astronomer, had the remote astronomical object been 'teleported' to earth from its point

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in spacetime $(\tau_{\mathrm{S}}, \boldsymbol{x}_{\mathrm{S}})$ ('S' for source/star/supernova...) with the retarded conformal-time, $\tau_{\mathrm{S}} := \tau_{\mathrm{A}} - r$, where

$$r := \sqrt{\sum_i (x^i_{\mathrm{A}} - x^i_{\mathrm{S}})^2} \equiv \|\boldsymbol{x}_{\mathrm{A}} - \boldsymbol{x}_{\mathrm{S}}\| = \tau_{\mathrm{A}} - \tau_{\mathrm{S}}\,. \tag{46}$$

To calculate the luminosity distance of an isotropically radiating object, S, we first note that, from (5) (with $g \mapsto \tilde{g}$ there) and (44), the expression for $\Theta^{\mu\nu}(x)$ derived from a single plane-wave is constant throughout spacetime. It follows that, by superposing our high frequency plane-waves, with random polarizations, an outgoing (incoherent) spherical wave can be represented, originating from S, whose associated $\Theta^{\mu\nu}(x)$ suffers only from the standard geometric attenuation,

$$\propto \frac{1}{4\pi r^2}\,, \tag{47}$$

present also in flat spacetime, with r given by (46). However, this Poynting flux is not what the astronomer would measure for three related reasons. First, it is coordinate dependent. In accordance with the principle of general covariance, measurements can only be associated with coordinate independent quantities, notably local ratios between quantities of the same type. Second, (47) is missing the proportionality constant. To determine its value, even in the x coordinates, we need first to define what it means to 'teleport' an object; to determine, in what sense can S at x_{S} and its teleported copy at x_{A} be considered the 'same', given that the corresponding local ZPF is different in our coordinates x (Recall from section 2.3 that nothing, other than mutual interaction via the ZPF, 'fixes' the scale of individual particles, elementary or composite). Considering the 'slimness' of our equivalence principle, the most we can say is that, in their respective local x coordinates, the two copies are represented by the same flat spacetime ECD solution modulo some yet unknown scale transformation (or else astronomers would have been measuring strange spectra, not related to terrestrial ones via simple scaling of the frequency axis). Third, the spherical retarded wave constitutes but a fraction of the total retarded field generated by S, responsible for breaching its equilibrium with the surrounding ZPF. In flat spacetime, global e-m conservation then guaranties that the associated Poynting flux has the same meaning—that of e-m flux—also when the wave is subsequently absorbed by matter (see section 3.1.4). Without global e-m conservation, as in curved spacetime, this meaning of the Poynting flux is lost.

In light of the above obstacles, the only conceivable conversion of the Poynting flux, Θ^{0i}, to a measured e-m flux, is to divide the former by the local energy-density of the ZPF, $\rho \equiv \tilde{P}^{00}$ (up to a constant representing the choice of units). The rational for this is rooted in our slim version of the equivalence principle: Any energy-flux standard, and its teleported copy, are represented in their local(-ly flat) x coordinates by the same flat ECD solution modulo scaling (13). As argued in section 2.3, this equivalence must include the ZPF surrounding the 'matter' ECD solution, as the two are just different facets of the same object. It follows that rather than using an explicit energy-density standard, derived from an ECD solution involving matter, one may as well use ρ, as the ratio between the two (both having scaling dimension -4) is scale invariant. Now, in the local x coordinates, Θ satisfies ordinary e-m conservation hence ρ must also set a standard for energy-flux. Note that, in a more accurate analysis, the part of the fluctuations, p^{00}, coming from the ZPF, should be added to $\tilde{P}^{00}$ above. However, from our discussion in section 4.1, the main contribution to $\tilde{P}^{00}$ comes from the vast void between lumps of matter, hence in the *current* epoch of the universe, p^{00}'s contribution can safely be neglected. For this reason, in conjunction with the effective constancy of a (hence of also of $\tilde{P}^{00}$), all the classical results of GR on galactic scales, such as gravitational redshift, time dilation etc., are retained.

The above discussion implies that, the ratio between the readings of the energy-flux at x_{A} and at some point, x_{B}, taken along the null geodesic connecting x_{S} and x_{A}, is

$$\frac{\mathcal{F}_{\text{A}}}{\mathcal{F}_{\text{B}}} = \left(\frac{r_{\text{B}}}{r}\right)^2 \frac{\rho(\tau_{\text{B}})}{\rho(\tau_{\text{A}})}\,, \tag{48}$$

where r_{B} is r (46) with $x_{\text{A}} \mapsto x_{\text{B}}$ there. Next, defining the *proper distance*, $d_{\text{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau)$, between two points at a given conformal-time, as the minimal number of local length gauges exactly fitting between them, the homogeneity of space implies

$$d_{\text{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau) \propto \|\boldsymbol{x} - \boldsymbol{x}'\|\,, \tag{49}$$

with a proportionality constant depending on the choice of standard length gauge and on τ. Defining the *redshift*, z,

$$(z+1) = \frac{\text{wavelength measured by astronomer at } x_{\text{A}}}{\text{wavelength measured near source at } x_{\text{S}}}\,, \tag{50}$$

by virtue of our monochromatic plane-waves retaining their wavelength in our coordinate system, x, (49) implies that, a standard length gauge, when teleported to an earlier conformal time, measures a larger coordinates interval by a factor $(z+1)$, i.e.,

$$d_{\text{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau_{\text{S}}) = (z+1)^{-1} d_{\text{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau_{\text{A}})\,. \tag{51}$$

Letting x_{B} approach x_{S}, and recalling the definition of r_{B}, we have

$$4\pi \mathcal{F}_{\text{B}} r_{\text{B}}^2 \equiv \alpha(z+1)^2 \left[4\pi \mathcal{F}_{\text{B}} d_{\text{P}}^2(\boldsymbol{x}_{\text{S}}, \boldsymbol{x}_{\text{B}}, \tau_{\text{S}})\right] \xrightarrow[x_{\text{B}} \to x_{\text{S}}]{} \alpha(z+1)^2 L \tag{52}$$

independently of x_{B} (equivalently, r_{B}), with $\alpha^{-1/2}$ the proportionality constant in (49) at $\tau = \tau_{\text{A}}$. Implicit in (52) is our assumption that, the astronomer's luminosity measurement, L, of a teleported copy of S, equals to the luminosity reported by that astronomer, had he been teleported to x_{S}. Combined with (48), we get

$$\mathcal{F}_{\text{A}} = \frac{\alpha L}{4\pi r^2} \frac{\rho(\tau_{\text{S}})}{\rho(\tau_{\text{A}})} (z+1)^2\,. \tag{53}$$

As a final step, we wish to express the ratio, $\rho(\tau_{\text{S}})/\rho(\tau_{\text{A}})$, in (53) as a function of z. Under our assumption that, S and its teleported copy at x_{A}, are both represented in their local x-coordinates by the same flat spacetime ECD solution modulo some scale transformation

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(13), and given the scaling dimension of energy density, -4, plus the required scale factor mandated by (51), $\lambda = z+1$, we get at once

$$(z+1) = \left(\frac{\rho(\tau_{\mathrm{A}})}{\rho(\tau_{\mathrm{S}})}\right)^{\frac{1}{4}} = \left(\frac{a_{\mathrm{A}}}{a_{\mathrm{S}}}\right)^{-\frac{3}{2}}, \tag{54}$$

with $a_{\mathrm{A}} := a(\tau_{\mathrm{A}})$ etc., and, in the second equality, (40) has been used for the current epoch of the universe.

There is, however, another way to compute the energy-flux of a distant object, using the language of 'photons'. To cut a long story short, we shall assume that, notwithstanding our attitude towards them from section 3.1.4, phenomenologically, as in flat spacetime, one can also think of photons as massless particles. Using (50), the counterpart of (53) which is based on the reading of an efficient photoelectric cell, should read

$$\mathcal{F}'_{\mathrm{A}} = \frac{L}{4\pi\, d_{\mathrm{P}}^2(\boldsymbol{x}_{\mathrm{A}}, \boldsymbol{x}_{\mathrm{S}}, \tau_{\mathrm{A}})}\, \frac{1}{(z+1)^2}\,. \tag{55}$$

(This standard expression can be found in virtually any textbook on GR, only there, the proper-distance (33) derived from the metric is being used). The first term in (55) is just the luminosity, L, divided by the surface area of a sphere with proper radius $d_{\mathrm{P}}(\boldsymbol{x}_{\mathrm{A}}, \boldsymbol{x}_{\mathrm{S}}, \tau_{\mathrm{A}})$, over which the emitted photons are distributed. The second term involves our slim equivalence principle, namely, the assumption that, the proportionality constant relating the measured energy and frequency of a photon, is the same at x_{A} and x_{S}, hence one power of $(z+1)^{-1}$, and that the rate at which photons penetrate the sphere of radius r, on which earth resides, is diminished by another similar factor.[15] With (54) satisfied, either (53) or (55) lead to a luminosity distance (45) which reads

$$d_{\mathrm{L}} = \alpha^{-1/2}(z+1)r\,. \tag{56}$$

To make contact with standard cosmological terminology, we take the derivative of (51) with respect to τ_{S} at $\tau_{\mathrm{S}} = \tau_{\mathrm{A}}$. The derivative of z is computed using (54) and (42), giving

$$\frac{\mathrm{d}}{\mathrm{d}\tau} d_{\mathrm{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau) = d_{\mathrm{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau)\frac{\mathrm{d}}{\mathrm{d}\tau'}\left(\frac{a(\tau')}{a(\tau)}\right)^{3/2}\Bigg|_{\tau'=\tau} := H^*(\tau)\, d_{\mathrm{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau)\,, \tag{57}$$

where the dimensionless Hubble 'constant',

$$H^*(\tau) = \frac{3}{2a(\tau)}\sqrt{\frac{C}{3} - \frac{\Lambda}{3}a^4(\tau)}\,, \tag{58}$$

[15] This follows from the 'conservation of photons': In the x coordinates, as in flat spacetime, the number of photons penetrating a sphere of radius R per unit oscillation of the pulse is independent of R. A non-vanishing z only means that the astronomer considers a unit oscillation as a longer period by a factor $(z+1)$, compared with an observer at S.

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is related to the usual Hubble constant,

$$H_0^{-1} := \frac{\mathrm{d}}{\mathrm{d}z} d_{\mathrm{L}} \bigg|_{z=0} , \tag{59}$$

via $H_0 \equiv \alpha^{1/2} H^*$.

The (locally) exponential expansion implied by (57) (even for a constant H^*) is misleading in the following sense. Denoting by $\ell(\tau)$ the coordinate interval spanned by a comoving standard length-gauge, $d_{\mathrm{P}}(\boldsymbol{x}, \boldsymbol{x}', \tau)\ell(\tau) = const$ and (57) imply the shrinkage $\dot{\ell} = -H^*(\tau)\ell$. By our slim equivalence principle, this must also be true for the conformal-time interval between two consecutive ticks of a comoving physical clock and, in particular, of a 'light clock'—two parallel mirrors, separated by a single standard length gauge, with light ray bouncing in between. This particular choice is necessary in order to conform with the implicit $c = 1$ choice of units used throughout the paper. It can then be easily shown that the growth rate of d_{P} with respect to the time, t^*, shown by a comoving light-clock, satisfies

$$\frac{\mathrm{d}}{\mathrm{d}t^*} d_{\mathrm{P}}\big(\boldsymbol{x}, \boldsymbol{x}', \tau(t^*)\big) = \Omega H^*\big(\tau(t^*)\big) d_{\mathrm{P}}\big(\boldsymbol{x}, \boldsymbol{x}', \tau(t_0^*)\big) , \qquad \Omega = \frac{\mathrm{d}\tau}{\mathrm{d}t^*}\bigg|_{t_0^*} \tag{60}$$

$$t^* = \Omega \int^{\tau} \mathrm{d}\tau' e^{\int_{\tau_0}^{\tau'} H^*(\tau'')\mathrm{d}\tau''} . \tag{61}$$

Chosing $\tau_0 \equiv \tau(t_0^*) = \tau_{\mathrm{A}}$, our consistent $\alpha^{-1/2}$ proportionality constant in (49) implies $\Omega = \alpha^{1/2}$. Equation (60) can be naively interpreted as, either an expansion of the universe, or else a collective shrinkage of matter—neither will be truly adequate.

Finally, we can test our model against observations. As all of our variables and constants are just numbers, whose meanings change with τ, we can only compare (current) dimensionless observables with their corresponding ECD predictions. Starting with the dimensionless luminosity distance $d_{\mathrm{L}} H_0$ (note the disappearance of α, as must be the case for a dimensionless quantity) of supernovae data (see e.g. [1]), to express r in (56) in terms of z, we solve the first order o.d.e. (42) with a_{A} as (sole) initial condition, substitute the (numerical) solution into (54), and solve for $r \equiv \tau_{\mathrm{A}} - \tau_{\mathrm{S}}$ as a function of z, parametrically depending on a_{A}, C and Λ. For astronomers to currently see a redshift (rather than blueshift), $a(\tau)$ must be a monotonically *decreasing* function in the current epoch of the universe, further taken to be positive. With the slope of $d_{\mathrm{L}} H_0$ at $z = 0$ fixed at 1, we are still left with a (one dimensional) line in our original three dimensional parameter space, whose respective graphs fit excellently the supernovae data, virtually coinciding with the best ΛCDM fit for the current data limit $z \lesssim 1.2$.[16] All members of this set of graphs have a *negative* Λ. We further verify that a finite segment of this line corresponds to parameters conforming with our $\epsilon \ll 1$ assumption by comparing the dimensionless quantity $G\rho(H_0)^{-2}$ with its (current) estimate of $\sim 10^{-5}$ (based on an ordinary matter density estimate of $10^{-28}\mathrm{kg/m}^3$), arriving at a consistent ϵ in the huge rage $10^{-1} - 10^{-16}$. To further be compatible with a galactic-scale

[16]This is so because, with the current limit on z, to match the data one only needs to further tune the second derivative of $d_{\mathrm{L}} H_0$ at $z = 0$.

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gravity, effectively independent of Λ, we perform the following test on our previous subset: A negative Λ in linearized gravity, modifies the r.h.s. of (23) $\nabla^2 \mapsto \nabla^2 + a_{\text{A}}^2|\Lambda|$, resulting in a Green's function which is a spherical Neumann function, coinciding with the original for $r_{\Lambda} \lesssim 2\pi a_{\text{A}}^{-1}|\Lambda|^{-1/2}$. As $r_{\text{H}} := H_0^{-1}c$ defines a cosmological length scale, for the effects of Λ to be appreciable, at most, on cosmological scales, we must have

$$\frac{r_{\text{H}}}{r_{\Lambda}/\sqrt{\alpha}} \equiv (2\pi)^{-1}a_{\text{A}}(\alpha|\Lambda|)^{1/2}cH_0^{-1} \equiv (2\pi)^{-1}a_{\text{A}}|\Lambda|^{1/2}c(H^*)^{-1} \lesssim 1\,, \tag{62}$$

which is verified to be the case. Note that r_{Λ} must be multiplied by $\alpha^{-1/2}$ in order to convert it to the units used to express r_{H}.

Besides the luminosity distance, our cosmological model has other commonalities with the standard model: Using (51), the observed angular diameter of a sphere with proper diameter D is $\delta\theta = \alpha^{1/2}(z+1)D/r \equiv D(z+1)^2/d_{\text{L}}$, agreeing with ΛCDM, with the same deflection point at $z \approx 1.5$, beyond which the sphere increases its apparent size with increasing z; Using (56), the sphere's surface brightness, $\mathcal{F}/(\delta\theta)^2$, has the usual $\propto (z+1)^{-4}$ dependence. It follows that by matching only the luminosity distance of ECD with that of ΛCDM, all other direct confirmations of of the latter, such as the (observed) number of galaxies of redshift less than z, are guaranteed to match as well.

For the sake of completion, an important caveat must be mentioned with regard to the use of supernovae as standard candles. As explained earlier, our analysis tacitly assumed that S, and it teleported copy at x_{A}, can both be represented in their respective local x coordinates by some flat spacetime ECD solution, so that teleportation can be given a definition (teleported S solution=original solution, scaled by $\lambda = z+1$ in (13)). This assumption is consistent with ECD's alleged statistical theory, QM: If $\psi\left(t, \boldsymbol{x}^{(1)}, \ldots, \boldsymbol{x}^{(n)}\right)$ is a solution of Schröinger's equation, for a set of Coulombly interacting charges of masses $m^{(b)}$ ($b = 1, \ldots, n$) then so is $\bar{\psi} := \psi\left(\lambda^{-1}t, \lambda^{-1}\boldsymbol{x}^{(1)}, \ldots, \lambda^{-1}\boldsymbol{x}^{(n)}\right)$ for the modified masses $\bar{m}^{(b)} := \lambda^{-1}m^{(b)}$, and the *same* charges and $\hbar$, $\forall\lambda > 0$ (We restrict ourselves to the Coulomb interaction since, in [5], we argued that it is the only two-body interaction with a physical meaning—the rest being merely phenomenological potentials). The consistency then follows when teleported standard ECD length, time, mass and charge gauges scale as λ, λ, λ^{-1} and λ^0 respectively (section 2.2), and from $[\hbar] = ML^2/T$. More explicitly, since the result of any measurement is computed from a dimensionless combination of variables and constants, when they all scale in accordance with their physical dimension, the effect of scaling cannot be observed; The above active transformation is 'undone' by a similar transformation of the measuring devices. The source S can even include linearized gravity, (23) (24), in its description. In this case, teleportion, expressed in local x coordinates, reads: $\bar{\Phi}(x) := \Phi(\lambda^{-1}x)$, $\bar{p}(x) := \lambda^{-4}p(\lambda^{-1}x)$, $\bar{G}_{\text{Newton}} := \lambda^2 G_{\text{Newton}}$, where G_{Newton} is the dimensionful Newton's constant (see remarks at the end of the introduction to section 4). Note, again, the consistency with $[G_{\text{Newton}}] = L^3/(MT^2)$. However, in a supernova, among other exotic astronomical process (quasars...?), linearized gravity cannot be fully trusted. As it stands, therefore, a teleported supernova is not a completely well defined notion. Nonetheless, the luminosity curves of redshifted supernovae do appear dilated by a factor $z+1$, without any further systematic dependence on z, consistent with linearized gravity being a decent approximation in this case.

4.2.3 Beyond the current epoch of the universe

We conclude the section on cosmology by briefly extending our model to much earlier and much later (conformal-) times. Starting with the future, proper distance between comoving matter will keep increasing, a will keep decreasing and H_0 increasing. As a result, ϵ in (37) will get even smaller than today (but this is inconsequential as our model already assumes $\epsilon = 0$) and the Λ term in (42) will become negligible (Note the role reversal of ordinary e-m and the Λ term in our model, compared with the standard one). The divergence of ρ when a approaches 0 at some *finite* τ, will happen in the infinitely remote future. That is, using (58) and (61), it can easily be shown that the number of ticks of a comoving clock until the catastrophe at $a = 0$ happens, is infinite. The accelerated expansion of the universe should then continue for ever in a naive extrapolation. This, however, would mean that, advanced fields adjunct to particles in the future, are infinitely blue-shifted, and infinitely enhanced at present, implying a divergent ρ. Consistency of our model therefore requires that all matter is eventually either annihilated or else gets trapped in black-holes (with no advanced fields escaping it). In the former scenario, the absence of any measurement device implies that, the divergence of ρ at $a = 0$, can be regarded as a mere coordinate artefact. Consequently, equation (42) can be integrated to negative a's and our current 'aeon' (to paraphrase Penrose[17]) continued smoothly to the next one. An appealing candidate for this next aeon is the 'CPT image' of the current one, namely, ECD pairs are gradually created, condensing into antimatter (relative to present-day matter), leading to a contracting aeon with a reversed arrow of time (recall section 2.1). As we shall see shortly, the final part of that aeon could, similarly, be smoothly continued into the initial part of ours, and a cyclic universe would ensue.

Next, moving *backwards* in time, into the distant past, our model depicts the following picture. At first, the (proper) voids between galaxies begin to close, leading to an inconsequential increase in ϵ (At a certain point, though, the finite value of ϵ, and its dynamics, must be incorporated into the model. This poses a serious mathematical complication. As exemplified by the eventual annihilation of all matter, the ZPF at any given time is the result of both future and past radiation fields of matter. Although not affecting the qualitative picture of a monotonically increasing ϵ, this complication can greatly change the luminosity distance of extremely high redshift objects). Although (58) is no longer exact, it is clear that, beyond a certain point, Hubble's constant starts increasing. Moving further into the past, the effect of a negative Λ is to render $a(\tau)$ increasingly more convex. As the combined radiation+matter ρ_{total} becomes negligible in (42), $a(\tau)$ approaches the de-Sitter form, $\sim |\Lambda|^{-1/2}(\tau - \tau_0)^{-1}$, for some finite τ_0, taken to be 0 without loss of generality. Also diverging is the coordinate measure of any standard length gauge (the inverse of the proportionality constant in (49)) as well as H^*. However, since ECD particles have a finite size, before the singularity is reached, all inter-particle voids disappear and the universe becomes a hot ECD

[17]Penrose's model involves the Hawking evaporation of black-holes. ECD, on the other hand, provide a perfectly consistent way of dealing with beyond-horizon physics of matter which may reveal yet unknown consequences of such matter annihilation.

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plasma with a complete symmetry between negatively and positively charged ECD matter[18]. Recalling the discussion in section 4.2.1, such an exotic ECD matter is characterized by an exotic equation-of-state, viz., one differing from (37), eliminating the de-Sitter singularity. A further consequence of the disappearance of ordinary matter is the associated disappearance of the arrow-of-time (recall section 2.1) facilitating the smooth cyclic merging of our aeon's beginning with the end of the following aeon.

The flatness problem which inflation aimed to solve (insofar as one considers it a problem) disappears by virtue of a being a monotonically *decreasing* function of τ. In a curved space model ($k = \pm 1$ rather than our choice $k = 0$), the r.h.s. of (42) receives a term $\mp k a^2$. Using (58), (42) and (40) (which can be shown to apply also for $k = \pm 1$) we get

$$\rho_c = \frac{3}{8\pi G}\left(\frac{9}{4}(H^*)^2 + \frac{\Lambda}{3}\right) ,$$

where ρ_c is the *critical density* at a given time, defined as the density implying $k = 0$. It then readily follows that an arbitrary ratio, ρ/ρ_c, in the early universe, rapidly converges to 1—opposite than in the standard model.

The second problem motivating inflation—the horizon problem—is also rendered a non problem by our model. In the standard big-bang picture, the vanishing of the scale factor at the moment of the big-bang entails the physical divergence of the energy density, and there is no sensible way of extrapolating the physical scenario underlying the Friedman model to negative times. This, indeed, does not leave enough time for matter inside the 'sphere of last scattering' (SoLS) to thermalize. In our model, as we have seen, the singularity of a at $\tau = 0$ is just an artefact of using the wrong equation-of-state in the early universe. As soon as the arrow-of-time comes into existence, with its present-day direction (recall that it reverses direction somewhere in the distant past, when it is 'glued' to its CPT imaged aeon) primordial (exotic) ECD matter begins thermalizing and there is no simple bound on the duration of this thermalization epoch, consistent with the observed near-perfect thermal equilibrium of the SoLS.

To complete the picture, we move again *forward* in time, starting with a universe composed of some opaque exotic ECD matter, a non negligible portion of which is therefore made of charged particles. Condensation around slightly over-dense regions then ensues under the long-range force of linearized gravity[19]. As the universe is too dense for the ZPF to retain its current meaning, or even exist altogether, the very mechanism of fixing the scale (mass) of particle is absent from that primordial universe. In light of ECD's scale covariance, therefore, the only non arbitrary candidate for the spectral distribution of the fluctuations, is a scale invariant one.

As in the standard model, the 'plasma part' of the exotic matter begins to oscillate while the (possibly dominant) neutral part, which is much less affected by radiation pressure,

[18] This exotic ECD matter, we conjecture, is normally classified as 'jets', as seen in particles accelerators.

[19] The attraction basin of such denser regions is restricted to some multiple of $r_{\mathrm{H}} = cH_0^{-1}$ which, depending on the parameters, might violate (62), meaning that some Λ dependent corrections to linearized gravity should be included.

behaves qualitatively like dark-matter in the standard model. However, not only is the exact physics of this exotic ECD matter very unclear at present. Our very description of the process involving it is somewhat misleading. As previously explained, once teleportation of standard gauges becomes ill defined, the notions of space, time, pressure etc. must first be given precise intrinsic (x coordinates independent) meanings which, again, requires a clear understanding of the relevant physics. We therefore shall not attempt to reproduce the observed BAO spectrum or the eventual relative frequencies of the various light elements.

Finally, 'ZPF dark-matter' also plays a central role in the universe's subsequent large structure formation. An initial condensation of matter in some region, 'frees space' for the ZPF to contribute to the local energy density. Recalling our discussion of the Bullet cluster in section 4.1.2, matter, when packed into a few high density region, rather then being evenly spread out, maximizes the energy density of the ZPF which, in turn, attracts matter towards such ZPF-energy dense regions. This feed-forward process is then expected to lead to the formation of aggregates of matter at a much faster pace than expected by naive calculations, ignoring the ZPF.

5 Conclusion

The thesis advocated in this paper is that, the failure to realize at the turn of the twentieth century, the degree to which classical electrodynamics (CE) was pathological, could be the root cause of most of the outstanding problems in contemporary physics. A previous paper [5] demonstrated that, once CE is properly fixed, the persistent problem concerning the conceptual foundations of quantum mechanics (quantum gravity) is resolved: QM, it is argued there, is a statistical description of CE (generally covariant CE resp.). The current paper extends the consequences of properly fixing CE to other outstanding problems in contemporary physics. In the field of particle physics, the following mysteries are explained by our model:

• The quantization of the electric charge observed in all forms of matter.

• The common intrinsic angular momentum of all charged leptons, as well as their very similar, yet slightly different, viz., 'anomalous' g-factor.

Both two points above are explained by the unique ability of ECD particles to change scale. Scale covariance, a symmetry which most physicists would embrace for its aesthetic appeal, but reject on observational grounds, receives thereby an experimental support. Another one emerges from our interpretation of astronomical redshift.

• The wave-particle duality of light, manifested in the illusion of a 'photon' (in conjunction with [5]).

• The observed particle-antiparticle imbalance.

In the field of astrophysics, the following phenomena were explained:

• Dark-matter related phenomena, including many of its quantitative aspects, faithfully described by the MOND phenomenology, such as the baryonic Tully-Fischer relation. Our model further suggests that estimates of dark-matter in so-called pressure supported systems, such as clusters of galaxies, are groundless.

• The apparent correlation of (alleged) dark-matter density in the Bullet-Cluster, with the density of galaxies rather than gas. It is further predicted that the proportion of dark-matter in a cluster should be inversely correlated with the proportion of gas in its total ordinary mass.
• A cosmological model quantitatively conforming with ΛCDM with regard to the present acceleration of the universe and, qualitatively, with all other observations supporting it.
• Our model does not suffer from the two major problems motivating inflation theory—the particle horizon and flatness problems. Consequently, there is no need for 'inflationary dark-energy'. The Λ term in our model is just another term in Einstein's equations, on equal footing with the other two, as advocated in the introduction.
• By 'relieving $g_{\mu\nu}$ from its metrical duty', the conceptual difficulties of quantum gravity are eliminated.

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