Instant, Non-Transverse Actions:
Ampèrian Forces in an Electric Universe

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Abstract. We lay out the basics of an integration-based model assuming the multiscale nature of non-Lorentzian angular-dependent forces and longitudinal effects in an Electric Universe; and offer some overview of our research pertaining to the history, physics, and epistemology of E&M.

Introduction

How did electrodynamics turn into the synthesized electromagnetic theory we have today? The answer essentially lies in the relativity basis of the Lorentz force (starting with the introduction of the modifying concepts of Lorentz's microscopic electrodynamics).

The key ingredient to that synthesis is the decreed speed limit of information travel (the postulate that nothing travels faster than light, per Special Relativity's requirement that light travels at the same speed *c* in any inertial reference frame). Key likewise to that synthesis is the rise of "force fields," introducing a specific view of Nature wherein classical electromagnetic theory (having essentially blanked out the electrodynamic formulations of Ampère, Gauss, Weber, Neumann, and Ritz) finds comprehensive explanation only in the framework of relativity theory. Indeed, the view that the theory of Special Relativity (originally named the Lorentz-Einstein theory) provides the ultimate framework for the unification of electricity and magnetism in effect forces the original field-free description of electrodynamics (as Ampère initiated it) into the field-based theory of Faraday, Maxwell, Heaviside, Lorentz, and… Einstein. Magnetism is consequently interpreted as a relativistic effect, and relativity itself is accordingly seen as deriving from magnetism. What we have in our hands then is exactly the synthesis by which the original science of electrodynamics was redefined into the study of electromagnetic waves. Maxwell's equations (by way of Heaviside) were in fact intended as relativistic. In them, the electric and magnetic field vectors propagate at the speed of light (Maxwell's equations predict both the speed of light and that of propagating fields). From this perspective, a correct electromagnetic theory must ultimately be expressed in the form of wave equations of electric and magnetic fields in vacuum (being ultimately about light), and thus can only be relativistic. We accordingly end up with an electromagnetic synthesis built on relativistic mechanics and field theory, i.e. with electrodynamics redefined as electromagnetism for Special Relativity.

Hence, the physics analytically depicted today in the field-based synthesis of electricity and magnetism is essentially a derivation from vector field mathematics. Contemporary physicists routinely use analytical mechanics and wave quantum physics to demonstrate the Lorentz force and underscore its relativistic use for electrodynamics redefined as the study of electromagnetic waves. When electrodynamics is mathematically reframed and understood from the premise of a field theory, we get Maxwell's classical electrodynamics culminating with the wave nature of radiation phenomena. This undoubtedly magnificent theory mathematically hinges around the propagation equation of the electric and magnetic fields, and the transversal, field-based Lorentz force. In this model, electromagnetic "force" actions must conform to light speed retardation, and therefore reduce to the physics of propagating radiative effects (and, therefore, to the mathematics of wave equations).

Before being so redefined to fit the relativistic paradigm of electromagnetic field theory, the early days of electrodynamics applied first to moving currents in conductors (on the basis of Ampère's force action between any two differential conducting elements) and later to moving electric charges (on the basis of Weber's relative velocity law of interaction between elementary charged particles) promised and yielded remarkable results (e.g. the existence of fundamental noncovariant action forces in nature) eventually deemed more convenient to essentially pay no mind to by the established world of standard theoretical physics. When electrodynamics is physically and mathematically understood from the premise of distant-action theory, we get Ampère's electrodynamic theory culminating with his angular-dependent law of electric force action ranging through all the possible positions of two relative filamentary current elements. This theory hinges around the principle of equal action and reaction (Newton's third law) and the existence of longitudinal, field-less, Ampèrian interactions. Of the fundamental law the theory rests on, Maxwell himself once wrote that it "must always remain the cardinal formula of electrodynamics."

This, we will only too briefly consider in the following three sections of this Picture of the Day article (in hope to further discuss the subject with other Electric Universe advocates and contributors), treating 1) of the electric meaning and validity of instantaneous force actions-at-a-distance; 2) of the empirically tested mechanical force actions of current in various conducting media and first observations of the pinch effect; and 3) of our hypothesis of non-transverse actions of Ampèrian electric forces within an electrically active astrophysical environment featuring the phenomena of filamentation, long-range attraction, and short-range repulsion.

1. Instantaneous Transmission of Distance Force Actions in an Electric Universe

An instant action-reaction force model for electrodynamic phenomena was what André-Marie Ampère, the original founder of a comprehensive electrical theory of magnetism, based his distance and angular-dependent treatment of force between current elements on. All electric force interactions, not merely all electrostatic actions, imply and rest upon instant action. Radiation effects alone are subject to and physically translate time delay at speed c.

Given the relativistic postulate about the speed of electromagnetic information as the limiting (invariant and finite) universal speed, it is decreed that infinitely faster than light speed is proven falsified. Because relativists equate light's maximum speed with the fastest possible information speed in the physical universe, they naturally mischaracterize the case for a near infinite gravity speed to be the same (that is, the same mistake) as assigning a near infinite speed to light itself. Of course, that is not actually what a case for a near infinite speed of force transmission does when included within an electrostatic model of gravity.

The crux of the matter as to do with the fact that the electrostatic field equations (Poisson's equation and the regular Coulomb-based **E**-field equation) do not include the effect of Maxwellian electrodynamics, which is predicated upon magnetism.

To understand the contention of relativist electrodynamicists, we need to understand how the inclusion of **B**-field effects make their case for electromagnetic time delay. Their case, however, does not actually hold when we consider, not light and its limited speed propagation (which is so constrained due to the state of orthogonality of the **E**-field and **B**-field making up electromagnetic energy), but the *electric force* itself. Our argument here is that the case for instant action or speed of information transmission can be made on the basis of Ampère's Newtonian electrodynamic theory applied to the Electric Universe model of universal matter interaction, which is electrical in nature. Hence, it is necessary to differentiate the transversal phenomenon of electromagnetic waves in a medium (which is a propagation phenomenon) from the instant longitudinal connection between all matter across the Universe, which is the electrical connection itself (consisting, to start with, of the electrostatic interaction between the sub-particles of all matter).

However, how can we, bound as we are to the experience of time, actually conceive of such a pervasive, delay-free interaction across the physical world? An analogy would be with the speed of thought, which neurologically, is electrically conducted. In the case of thinking itself, taken as an act of the *active intellect*, the knowing interaction of the mind with whatever it knows or thinks about is retardation-free, like a glimpse of the undying *now* of eternity rightly conceived.

Notice that the analogy holds, even though, from the viewpoint of the nature of finite cognition, the intellect passes from potentiality to actuality, the very distinction of which entails temporality. In other words, there is such a thing as *time*, separated from space, because there are at least two distinct states of existence, potency and actuality (the condition of possibility of what we experience as and call 'time' is this transformative differentiation).

The speed of thought, which physiologically involves neurological electric signaling, is a measure of the mind's instant interaction with itself and the world it exists in. And this is like the instant electrical connection undergirding the dynamic structure of all physical matter. Notice how this view, appealing to the speed of thought as an analogy for instant speed of information transmission in physics neatly illustrates the mind-body connection rightly dear to the cross-disciplinary approach of the Electric Universe paradigm.

Whereas cognition as such, insofar as the intellect neither comprehends everything there is nor all it intends to grasp at once, betrays its finite nature. We think instantly—one might say *electrically*. But we understand, we grasp within the finite constraint of a cognitive motion from potency to actuality, which again is tantamount to what we call 'time.'

In physics today, the problem of the speed of force transmission for multiscale interactions in the Universe receives its mathematical treatment from the perspectives of two famous models of Nature: the first, predicated upon interactions *propagating* with a light-speed propagation delay; the other, upon instantaneous *force* interactions. The two descriptive players here are: 1) the 4-tensor equation of motion of General Relativity (according to which the motional curves of free particles are geodesics of contorted "spacetime"); and 2) the classic equation of motion of

Newtonian mechanics (according to which the path of a free particle is a geodesic of 3D space described in inertial frames). But the solution to the *relativistic* versus *non-relativistic* approach to this problem lies both in Wal Thornhill's electrostatic model of gravity—reassessing the gravitational interaction as a manifestation of the electrical force—and in Ampère-like angular-dependent electrical force actions (the angular-dependence factor of Ampèrian forces critically including the longitudinal component of Ampère's forgotten electrodynamics).

In the General Relativity model of Nature, a moving mass causes a disturbance to propagate with the speed of light through the deformed space surrounding that mass. In the conventional electromagnetic model derived from the Faraday-Maxwell paradigm of continuous form of action, a moving charge causes a disturbance to propagate with the speed of light through the electromagnetic field surrounding the charged object. The propagated disturbance in the space or field radiates in all directions. Thus, classical electrodynamics is conceived along the lines of classical relativistic mechanics, and all electromagnetic effects, whether force interactions or radiations, must ultimately conform to the physics of retarded interactions. The concepts of wave propagation and field tend to consequently conjure a view of Nature trapped within the spell of relativity and the restriction that the velocity of light be an absolute interaction limit in the Universe (in which case the latter cannot, in fact, be conceived to work as a connected system).

From the perspective of an Electric Universe, simultaneousness reclaims an objectively defendable, real meaning in physics. Simultaneousness of spatially separated events or instantaneousness of mutual force actions at a distance has a physical meaning not only through the universal electrostatic connection of atomic interactions, but through all electric force actions obtaining across the various scales of the physical Universe. Time is electrically the same everywhere.

The Faraday-Maxwell field theory of electromagnetic phenomena hinges around its harmonious conception of electromagnetic propagation as transverse oscillating waves of the electric and magnetic fields. By this model, the direction of motion in space of any point relative to both transversely interlinked fields of all electromagnetic radiations yields a velocity vector perpendicular to both. In this framework, the exertion of electrodynamic force actions is tantamount to orthogonality. Thus, applying the cross product of the **E** and **B**-fields to a given charged particle will always constrain it to a new direction necessarily perpendicular to the two orthogonally knitted electromagnetic field waves. From the Lorentz equation, we may vectorially express this transversal relationship of three variables (**E**, **B**, and v) as:

$$\mathbf{E}\hat{\mathbf{j}}\times\left(\frac{-1}{\mathbf{B}}\right)\hat{\mathbf{k}} = v\hat{\mathbf{i}}. \tag{1}$$

Being predicated upon the gradual abandonment of the action-at-a-distance model in favor of the continuous action model, this view of Nature needs to "confound space with matter," *dixit* Faraday himself. Ironically, the advent of the Relativity paradigm replaced Faraday's "mattered space" with the confounding mathematical fabrication of the so-called "spacetime continuum," treating t as if it were a fourth perpendicular vector in an invariant speed of light Universe.

The idea that time itself is orthogonal to three-dimensional space in the geometry of Minkowski's space, the basis of Einstein's theory of General Relativity, was added to Maxwell's theory. There is no time term in Ampère's (Newtonian) electrodynamic theory.

According to the theory of field mediation based on Maxwell's equations, electromagnetic fields propagate with finite velocity. This implies an unbreachable propagation delay, called electromagnetic retardation:

$$t_i = t - \frac{|\Delta \mathbf{r}|}{c} = \frac{|\mathbf{r} - \mathbf{r}_i|}{c}. \tag{2}$$

This t factor is what Oleg D. Jefimenko (the father of retarded field theories) integrated in his time-dependent electric and magnetic field equations:

$$\mathbf{E}(\mathbf{r},t) = \frac{1}{4\pi\varepsilon_0}\int\left[\left(\frac{\rho(\mathbf{r}_i,t_i)}{|\mathbf{r}-\mathbf{r}_i|^3} + \frac{1}{|\mathbf{r}-\mathbf{r}_i|^2\, c}\frac{\partial\rho(\mathbf{r}_i,t_i)}{\partial t}\right)(\mathbf{r}-\mathbf{r}_i) - \frac{1}{|\mathbf{r}-\mathbf{r}_i|\, c^2}\frac{\partial\mathbf{J}(\mathbf{r}_i,t_r)}{\partial t}\right]\mathrm{d}^3\mathbf{r}_i. \tag{3}$$

$$\mathbf{B}(\mathbf{r},t) = \frac{\mu_0}{4\pi}\int\left[\frac{\mathbf{J}(\mathbf{r}_i,t_i)}{|\mathbf{r}-\mathbf{r}_i|^3} + \frac{1}{|\mathbf{r}-\mathbf{r}_i|^2\, c}\frac{\partial\mathbf{J}(\mathbf{r}_i,t_i)}{\partial t}\right]\times(\mathbf{r}-\mathbf{r}_i)\mathrm{d}^3\mathbf{r}_i. \tag{4}$$

It is interesting that Jefimenko went on to generalize Newton's theory of gravitation by developing what he calls "the temporal aspect of gravitational interactions" (notwithstanding his taking into account the *absence* of a time variable in Newton's gravitational equation). What he essentially did consists in formally using the mathematical device of retarded field integrals to account for the two "force fields" supposed to mediate gravitational interactions, *viz*. 1) the regular gravitational field (generated by all masses), and 2) the "cogravitational" or so-called Heaviside's field (generated by moving masses):

$$g\,(\mathbf{r},\theta) = -G\,\frac{m\left(1-v^2/c^2\right)}{r^3\left[1-\left(v^2/c^2\right)\sin^2\theta\right]^{3/2}}\,\mathbf{r}. \tag{5}$$

Specifically, the Heaviside's field equation accounts for the retarded value of the gravitation field g for a fast moving mass m.

Maxwell's equations provide a very sound and complete description of electromagnetic waves. Jefimenko took the powerful model of Maxwell's description to apply it to gravitational field theory. He recognized that the mutual induction of **E**-fields and **B**-fields due to a moving charged particle according to Maxwell's synthesis of classical electrodynamics likewise applies when dealing with masses. **G**-fields behave like **E**-fields; while "cogravitational" (i.e. secondary *g*-fields) behave like **B**-fields. Both types of fields are induced by stationary, or steadily moving, or again accelerating masses. His therefore is a theory of Maxwellian gravitation—a gravito-electromagnetic wave theory (according to which gravity ends up with a transversal component) including time-dependent **E** and **B**-field equations, because both of the two gravity fields and the electromagnetic fields are changing with time, per Maxwell's partial differential equation descriptive format. In this framework, it is the orthogonal time delay of light dictated by the invariance of *c* that effects the manifestation and behaviors of gravito-electromagnetic fields.

Thus, when light and radiation are introduced as the new focus of electromagnetic theory, which was not a concern of pre-field electrodynamics, the notion of *force* ends up fitting into a model of Nature wherein interactions propagate with a finite velocity, that is, not instantaneously. But the Maxwellian representation of the electromagnetic field and the Lorentz force description of the motion of a charged particle in a time-retarded field of magnetic induction can neither account for nor describe all experimental results of electrodynamic force actions. The latter imply the non-violation of Newton's action-reaction law, which is a universal translation of force action-at-a-distance simultaneity consistent with an electrically connected Universe.

One may wonder why it is finally so crucial to maintain instant force interaction on a cosmic scale. Not going into the dynamic details of an answer already provided by Laplace in the 19th century, we can simply call attention to the fact that it is strictly consistent with how the electric force longitudinally operates on the atomic scale. In other words, there could be no matter whatever in the first place if it were not for the near infinite speed of the electric force interaction across the physical world, whatever the scale. Cosmologically therefore, this entails that gravity is ultimately the symptom of the universal electric interaction, as Wal Thornhill has long insisted on and proposed a model for, besides calling attention to the work of the late Tom Van Flandern—who notably demonstrated that the speed of gravitational interaction has no propagation delay in its action, experimentally measuring it to be 2×10^{10} faster than the speed of light. Thornhill's elegantly simple model [1] hinges around the critical fact that gravity itself involves and exists in the interactions of bodies comprised of atoms, the nuclei of which are made of elementary charged particles (electrons and protons), themselves made of positively and negatively charged sub-components. His model accordingly features it as a leftover effect of the incredibly powerful and ubiquitous electric force interaction. Notice that an electrical root model of gravity is strictly consistent with a sound atomic theory grounded in real physics, since the electrical structure of *matter* is where the variable called "mass" ultimately originates—which is why electromagnetism betrays intrinsic characteristics associated with mass. It follows that the equivalence of mass and energy is not in fact a Special Relativity-based derivation. Likewise, the subatomic electric dipole model for the origin of the gravitational effect seems to us to be the key alternative to the accepted geometric theory enshrined ever since 1915 in General Relativity's unphysical account of the gravitational interaction.

Yet in the current state of Einsteinian establishment physics, we are left dealing with the fixed and unchallengeable relativistic consequences of an intermediate field theory on electromagnetism and the speed of force action in the Universe, the latter being as it were "absorbed" by the propagative characteristics of the former. The reasoning underlying this state of affairs for electrodynamics turned into the synthesized electromagnetic theory in force today goes as follows, affirming the consequent in the process, which is fallacious to do: the electric and magnetic fields do not transform properly under Galilean transformations (since those transformations do not accommodate Special Relativity's invariant and finite speed for *c*). Therefore, electromagnetism violates the principle of Galilean relativity. Three conclusions "accordingly" follow:

1. Maxwell's equations are initially incorrect.

2. Galilean invariance (i.e. *regular relativity*) is valid for mechanics but not for electromagnetism.

3. Galilean invariance is incorrect, but there exists a more general invariance (albeit restricted to inertial reference frames), namely *special relativity*; and what the latter does is preserve the form of Maxwell's electrodynamic synthesis through the propagation equation of the electric and magnetic fields.

In fine, to reinstate the principle of sound causality in physics in accordance with an electrically invariant universal time, it is necessary to free electromagnetism from the invariance of light propagation at speed c and from the frame-dependent simultaneity the latter dictates per the principle of relativity. This task is predicated upon a threefold implementation, involving three correlated features consistent with an electrically active Universe: 1) recovering simultaneous action-at-a-distance theory; 2) restoring the suitability of Newton's third law of motion to the physics of electromagnetism (sacrificed in the process of implementing relativity to Maxwell's electrodynamic theory); 3) rediscovering the angular and longitudinal Ampère force actions as a sound way to bring 1) and 2) into play, from electrodynamic interactions of differential current elements to the interactions of cosmic current filaments carrying electricity through space.

2. Ampèrian Longitudinal Force Effects in Regular Conductors

Ampère's fundamental laws appertain to the actions of an electrical circuit on another circuit, or of some component of the same electrical circuit on its other components. Furthermore, they bear upon the controversial existence, within conductors, of longitudinal electrodynamic repulsive force effects obtaining between the successive differential elements of the current flowing through these conductors.

Two years after Ampère, prompted by Ørsted's 1820 discoveries, had set out on his own galvanizing journey into the new land of electrodynamic phenomena, Swiss physicist Auguste de la Rive invited him to join him to Geneva to conduct an experiment intended to establish once and for all the existence of mechanical actions of longitudinal force in current-carrying conductors. The experiment in question is famously known as the "hairpin experiment." The longitudinal effect observed in the hairpin experiment cannot be accounted by Grassmann's force $Id\mathbf{s} \times \mathbf{B}$ exerted on a current element $Id\mathbf{s}$. For Grassmann's force always acts orthogonally to $Id\mathbf{s}$, irrespective of the value of $\mathbf{B}$. When Grassmann published his own electrodynamic formula in the mid 1840's, he erroneously argued for the ultimate interchangeability of Ampère's angular-dependent force law and the Biot-Savart law (identically his own force law) applied to linear current elements. We need not expound here on the demonstration of Grassmann's historically consequential misjudgment. Suffice it to say that the Biot-Savart-Grassmann law violates Newton's instant equal and opposite action-reaction law. All-out agreement with Newton's third law is intrinsic to Ampère's electrodynamic theory and central force action formula. While, quantitatively speaking, the Biot-Savart law ends up conforming to Newton's third law provided its integration over an entire closed current loop, this operation proves a mere mathematical artifice failing to take in consideration the physically inviolable mechanical nature of the instant rectilinear forces involved in the observed dynamics of the Ampère-De la Rive qualitative demonstration.

Let us in fact return to this original experiment, to further describe and grasp its peculiarly important and historically disregarded electromechanical nature. When a current flows through the hairpin bridge normal to the two wires floating on both parallel liquid mercury-filled ducts, the bridge itself is repelled from the circuit's terminals with a net longitudinal force equal in magnitude and direction to the repulsive force arising between rectilinear current elements. Unlike the interaction between two straight parallel currents, the sign of the current bears no effect on the mechanical magnitude and direction of this repulsive force effect. This field-free electrodynamic phenomenon is embodied in Ampère's forgotten equal action and reaction mechanical force law, which we may qualitatively state as:

$$d^2\mathbf{F} = -\frac{\mu_0 I_\mathrm{i} I_\mathrm{j}\,\hat{\mathbf{r}}}{4\pi r}\left[\frac{\left(d\mathbf{s}_\mathrm{i}\cdot d\mathbf{s}_\mathrm{j}\right)}{r^2} - \frac{3}{2}\frac{\left(\hat{\mathbf{r}}\cdot d\mathbf{s}_\mathrm{i}\right)\left(\hat{\mathbf{r}}\cdot I_\mathrm{j} d\mathbf{s}_\mathrm{j}\right)}{r^4}\right]. \tag{6}$$

Notice that the net repelling force exerted on the hairpin's perpendicular bridge structure is obtained by integrating the differential filament vectors over its length only. While the overall resulting thrust effect arises in a closed circuit, the integration of that Ampèrian force does not range over the entire current loop. The Biot-Savart-Grassmann-Lorentz force law predicts no such net force in the longitudinal direction:

$$d^2\mathbf{F} = -\frac{\mu_0 I_\mathrm{i} I_\mathrm{j}}{4\pi r^2}\left[d\mathbf{s}_\mathrm{j}\times(d\mathbf{s}_\mathrm{i}\times\hat{\mathbf{r}})\right]. \tag{7}$$

It was Maxwell's childhood friend as well as Thomson's close collaborator of many years, Scottish mathematician and natural philosopher Peter G. Tait, who first reiterated the hairpin experiment in the early 1860's. Tait began by carefully testing and verifying Ampère's and De la Rive's longitudinal findings. Among the various subjects he devoted extensive scientific research to, his concerns at that time were particularly focusing on thermoelectricity. Being suspicious that external thermo-related effects, including thermoelectrical ones might have been involved in the unanticipated phenomena of Ampèrian tension between rectilinear current elements, Tait modified the original Ampère-De la Rive interface apparatus. He substituted a glass tube filled with mercury for the original copper-made hairpin shaped wire to minimize the rising of thermo-electric or other reactions potentially creeping in to the electrodynamics of the hairpin-fluid mercury conductive system. The adjusted experiment yielded the same irreducible force eff ects as he had perplexedly observed in the first place.

Carl Hering, president of the American Institute of Electrical Engineers (AIEE) from 1900 to 1901 and co-founder of the American Electrochemical Society (ECS) in 1902 (he also was its president from 1906 to 1907), was a particularly preeminent and proliferous contributor to the fields of electromechanics and electrochemistry in the late 19th and early 20th centuries. The extent of his investigations cannot be overstated. Among the many subjects he was keen to dedicate both experimental research and quantitative analysis on (albeit against strong academic streams and fashions) were co-linear (Ampèrian) repulsive force interactions of differential current filaments *Id***s** and *Id***s**' as well as compressive interactions of electric currents, notably uncovering new properties about the pinch effect phenomenon from excess current density flowed in various types of filamentary conductors. In the abstract of one of his very last papers (1926), entitled *The longitudinal force in conductors* [2], Hering acutely wrote:

> "The existence of a mechanical force in the direction of the axis of a conductor, the recognition of which the writer has been urging for many years, has been strenuously opposed by many (chiefly teachers and book writers) because it does not fit in with Maxwell's mathematical system, which recognizes only perpendicular forces."

A few years prior to another of Hering's co-related papers [3] treating of "high current densities in liquid conductors" and of the coexistence of longitudinal stress and transversal pinch pressure (suggesting the interplay of "some new electromagnetic forces"), the existence of a longitudinal mechanical tension caused by a high current density flow had been observed and discussed by Princeton physics professor Edwin F. Northrup. Hering identified glitches in Northrup's protocol and interpretation focusing incompletely on electric charge density distribution and points of energy convergence (pinch focuses). He went on to publish *Electromagnetic Forces; a search for More Rational Fundamentals; a proposed Revision of the Laws* in 1923 [4], wherein he described his own experiment, reimplementing the original Ampère-De la Rive solid metal and liquid mercury basic conductor apparatus [5] to test the longitudinal tension force and revise Northrup's incomplete take on longitudinal force effects. To yield the unpredicted observations of non-classical electrodynamic force actions and motions he recorded, Hering needed to supply his own current-carrying circuit experiment with very high current density flows. And that he did, corroborating what had been tested and observed a hundred years earlier by Ampère and De la Rive. Such an experiment, given the electric current intensity involved, can easily lead to a situation of wire explosion, which also verifies the occurrence of longitudinal tension forces in current-carrying circuits. It is interesting to note that the connection between the implications of Hering's experiment for real life electrodynamic applications and what is known today as EWM [6] is usually not made. Although applications of EWM substantiate the existence of mechanical Ampèrian stretching forces in wires loaded with and detonating under high current density charge flows, these effects are typically explained as increased thermal amplitude and shockwaves (energetic rippling).

The use of intense currents to record longitudinal force actions leading to the abrupt electrical explosion of metallic conductors was taken up in more recent times by Peter Graneau [7]. Graneau himself followed in the footsteps of Polish physicist Jan Nasiłowski, who conducted a prolific amount of tests in his lab in Warsaw in the 1960's. Nasiłowski accurately established the force necessary to rupture .5 mm current carrying copper wires. The clean, sharp-angled splits he recorded allowed him to further establish that they begin to swiftly form and materialize when current pulses of a minimum of 50 msec are used with a rate of charge flow of about 2,000 A. As observed by Graneau, no fusion from liquefaction of the wire under excess resistive ohmic heating is with any causal significance involved to explain the sudden breaking process. Based on the lab data he collected over many years, the increased radiative thermal reactions in the exploded wire do not bring about the explosion. Like Nasiłowski before him, what Graneau instead went on to observe was the presence of microscopic fractures devoid of thermal trademarks, pointing to powerful and sharp mechanical tension forces as main causative agents.

In their 1999 article *The fragmentation of wires carrying electric current* [8], treating of the physics of wire explosion, Sergei Molokov and John E. Allend made passing mention of those experiments that disconcertingly indicate that "the wires break in tension due to some longitudinal force," adding: "…the nature of this force being unknown." But they eventually resorted to focusing on "(i) the possible amplification of stress waves induced by the electromagnetic pinch force and (ii) the dynamic stress induced by the thermal expansion." With "stress waves" and "thermal expansion" as a more plausible explanation than an "unknown force" for the phenomenon of wire explosion, they undoubtedly stood a better chance to ultimately see their article published. It is only fair to underscore that Graneau's many publications offer a consistent and detailed tour of his extended research on this important, yet essentially eclipsed subject in contemporary theoretical physics environment.

In the early 80's, Graneau conducted his own version of the hairpin experiment at MIT. The hairpin conductor was placed on top of two elongated receptacles of liquid mercury separated by a common isolating wall, exhibiting longitudinal motion along both receptacles under application of 200 A and plus currents. Graneau also recorded the apparition of a new longitudinal form of electromechanical outthrust [9]. With the hairpin held in place, preventing from thrusting, jet reactions ensued squirting from the end points of the u-shaped conductor. Graneau carried out the test using increasingly high amperage values, all the way up to about 1,000 A, point beyond which the liquid mercury would start flying out and off the receptacles' boundaries.

Graneau further substantiated these observations by investigating the recoil effect in railguns [10]. This phenomenon cannot be accurately described if only Lorentz theory applies. According to the latter, the recoil force arising during the acceleration of the transverse conductor (the armature) ends up being absorbed by the field. As it turns out, "the Ampere recoil force arises from the current element repulsion across the comers of the rail gun circuit." [11]

When dealing with the conventional approach to railgun analysis, we essentially get a description of the system featuring exclusively the Lorentzian **B**-force on a current-carrying wire. The current running through the rails generates a **B**-field normal to them (forming between them). The flow of electrons running through the armature, itself normal to both the current-carrying rails and the **B**-fields they produce, experiences a Lorentz force-based (Laplace) effect mechanically thrusting it and whatever projectile it may carry for launching purposes with a magnitude proportional to both the **B**-field and the current *I*:

$$\left|\Delta \mathbf{F}_{\mathrm{T}}\right| = \left|I \Delta l \times \mathbf{B}\right| \tag{8}$$

$$\mathbf{F}_{\mathrm{T}} = \int I \mathbf{B} dl = \frac{L' I^2}{2}. \tag{9}$$

This does generally describe the overall transversally accelerated motion of the armature and corresponding total recoil of the railgun apparatus concomitantly splitting its rails under electromechanical stress. However, Graneau's experiments yielded evidence of other non-transverse deformation forces concomitantly at play with the recoil motion itself, the effects of which cannot be reduced to the overall orthogonal Lorentz "self-force:" compressive pinch forces, straight wire repulsion forces, Euler's longitudinal critical rupture load forces (varying with different solid conductors and their respective cross-sections), partition forces, and additional splitting forces. In all, Graneau found that Ampèrian and Lorentzian force components come into play as complementary players in the overall dynamics and complex force distributions observed around an entire current-carrying metallic circuit. Thus, as Graneau highlighted it in the abstract of a paper anticipating the publication of his extensive *Ampere-Neumann Electrodynamics of Metals* the following year:

> "In addition to the transverse forces [transverse relative to the circuit], which both laws predict, the Ampère electrodynamics requires a set of longitudinal forces that subject the conductor to tension. These longitudinal forces explain both electromagnetic jet propulsion and the recoil effect in a railgun." [12]

The experiments conducted in the late 19th century by Franz E. Neumann, contrasting the Amperian and Lorentzian repelling forces [13] and those devised by Prof. Panos T. Pappas in the 1980's using an electrodynamic impulse pendulum are also worth mentioning. Pappas, furthermore, conceived his own hairpin-like apparatus. He used a 2 m × 1.5 m u-shaped aluminum wire, 2 mm in diameter, which he suspended in the air, anchoring it to the ceiling. In such a configuration, the u-shaped wire structure, consistent with the Ampère-De la Rive metal-liquid mercury conductive interface, is held in such a way as to come in surface contact with two mercury-filled containers. Connecting the whole conductive system to a power source to form a closed circuit (Pappas used a car battery), the longitudinal repulsive force effect ensuing propels the u-shaped wire structure away from the battery over a distance of 2 cm.

A number of equally ingenious and still more recent experiments have been conducted to likewise establish the existence of a net longitudinal effect arising from forces obtaining in sections of conductors subjected to Ampèrian electrodynamic interactions [14]. They are virtually never heard of, the mainstream scientific literature having for the most part elected to avoid the subject altogether. With or without the attention and validation of the accepted science community, the fact remains that Graneau and other committed experimentalists have compellingly shown the generation of Ampèrian electromechanical forces in different conductive media to be strongly supported by experimental evidence. It is consequently fair to say that the irreducible existence of such non-Lorentzian electromechanical force effects qualitatively substantiates the fact that Grassmann's electrodynamic force formula and Maxwell's equations do not comprehensively describe all the forces generated by and around electromagnetic phenomena.

It is, moreover, worth pointing out that applications of such electromechanical principles and forces (including EWM) to different types of plasma conductors are essentially never remotely discussed and pursued. So far, we are not aware of much if any research having explored the occurrence of non-transverse Ampèrian force actions in current-conducting plasma structures, apart from the suggestions made by Jan Nasiłowski in his *A note on longitudinal ampere forces in gaseous conductors* [15]. As Nasiłowski puts it in the abstract of his exhorting note:

> “It is argued that longitudinal Ampere forces should act not only in solid conductors, but also in gaseous conductors like welding, switching and furnace arcs, and magnetically confined fusion plasmas. This topic is in need of quantitative research.”

Similar applications of the same principles and forces, owing to the scalability of electromagnetism and plasma physics, could also be made in relation to the filamentary regions of electrified plasma spanning across astrophysical and cosmic dimensions. We suggest here that this particular subject-matter, as yet essentially unexplored and therefore opened for research, finds its befitting natural place in the framework of the Electric Universe theory [16]. For example, such phenomena as tremendous as double-layer explosions could perhaps also be explained, in complement to the potential drop-induced strong electric fields arising across astrophysical plasma sheaths, in terms of forgotten actions of Ampèrian forces in naturally constricted plasma conductors carrying formidably high (cosmic) current densities. The possible relationship between non-Lorentzian angular-dependent forces and the dynamics of astrophysical structures is what we very succinctly wish to touch upon in the following and final section of this article.

3. Ampèrian Current Filament Force Distributions in Astrophysical Circuits

Could actions of angular-dependent Ampèrian electric forces apply to the phenomena of filamentation, long-range attraction, and short-range repulsion within an electrically active astrophysical environment?

Recall that it was Ampère’s own original endeavor to extend his elemental electrodynamics of mutual action of electric currents to *all* electromagnetic interactions. In an Electric Universe, the electric force is active everywhere from the smallest size scales of atomic and subatomic interactions to the largest size scales of Kpc electric currents flowing through the highly conducting plasma structures of space. Therefore, combining Ampère’s universal electrodynamic principle of mutual action of electric currents with the fractal-like scaling of electromagnetic phenomena and interactions in an Electric Universe, we suggest the theoretical application of Ampèrian angular and distance-dependent forces of electrodynamic actions to astrophysical plasma circuits to treat large-scale current-conducting filaments like the volume elements of current-carrying wires of Ampère’s electrodynamic experiments and analysis.

Thus, theoretically speaking, we essentially propose to expand the properties of the Ampère-type electrodynamic force law to all size scales. On the grounds of the extensiveness of the electric force acting across Nature and of the fractal-like coherence of properties of plasma up and down the scales of electromagnetic phenomena, we hold the Ampèrian method of mathematically devising differentials of force actions between current elements and integrating them over closed filamentary circuits to “calculate” the total force at play to also be pertinent to the study of the distribution of force actions in large macroscopic volume of current “elements” of astrophysical current-carrying plasma circuits. From the perspective of an electrically active Universe, we raise the question as to the possible presence and impact of Ampèrian non-transverse force effects in space, challenging the exclusiveness of the Biot-Savart-Lorentz long-range and short-range relation in describing force distributions in electrodynamical systems at all size scales.

In theorizing an integration of Ampèrian electrodynamics of small volume elements up to the astrophysical scales of current filaments carrying high electric charge densities through space, both the differential and line integral formulations of Ampère's angular-dependent force law prove useful tools to help us envisioning a multiscalar picture of non-transverse electromechanical forces in an Electric Universe. To do so quantitatively for open and closed filaments and interacting circuits of filaments, we use the basic mathematical ideas of breaking up and integrating arbitrarily large functions to analyze the electrodynamic Ampère force distributions across filamentary current-carrying structures in space.

Dynamic plasmas consist of current-conducting filaments. The general description of such filamentary structures of high electrical conduction in terms of their constituting forces relies upon the Biot-Savart law, embodying the conventional transverse Lorentz force. However, an electrodynamic description of these structures obeying the morphology of cosmic-sized strands of currents in relative motion should also include the irreducible electromotive force effects of angular-dependent current interactions to account for the non-transversal components of cosmic circuit force interactions.

Ampère used the mathematical device of a segment of a straight line or any portion of a space curve divisible into *n*th sub-curves to integrate over. Thus, the following integral

$$\int_{C\; a_{\mathrm{i}}}^{b_{\mathrm{j}}} \left(\mathbf{F} \cdot \frac{d\mathbf{r}}{ds} \right) ds \qquad (10)$$

specifically is a line integral ranging along an arbitrary circuital-like path *C*.

Now,

$$d\mathbf{r} = \mathbf{i}\, dx + \mathbf{j}\, dy + \mathbf{z}\, dz.$$

We can therefore restate Eq. (10) in terms of those vector components:

$$\int_{C\; a_{\mathrm{i}}}^{b_{\mathrm{j}}} \mathbf{F} \cdot d\mathbf{r} = \int_{C\; a_{\mathrm{i}}}^{b_{\mathrm{j}}} \left(f_1 dx + f_2 dy + f_3 dz \right). \qquad (11)$$

Taking this calculus-based idea and assuming that electrodynamic force actions can be broken down and recombined into an integral whole as in mechanics, we theoretically apply it to the dynamics of filamentary circuit interactions in space, assuming an all-size-scale coherency per the tenets of plasma physics holding in an Electric Universe. Taking Ampère's force action between two differential volume elements $d\mathrm{s}_{\mathrm{i}}$ and $d\mathrm{s}_{\mathrm{j}}$ separated by a distance *r* and integrating it to calculate the total action exerted on volume elements in interacting circuits yields the form of Ampère's force law interaction. By our multiscale hypothesis, this force phenomenon can be scaled up and applied to long-rage attraction and short-range repulsion astrophysical dynamics, as a second action force distribution, besides the Lorentz transverse force distribution.

$$\mathbf{F} = \frac{\mu_0 I_{\mathrm{i}} I_{\mathrm{j}}}{4\pi} \oint\oint \frac{1}{r^2} \left[3\left(\hat{\mathbf{r}} \cdot d\mathbf{s}_{\mathrm{i}}\right)\left(\hat{\mathbf{r}} \cdot d\mathbf{s}_{\mathrm{j}}\right) - 2\left(d\mathbf{s}_{\mathrm{i}} \cdot d\mathbf{s}_{\mathrm{j}}\right) \right] \hat{\mathbf{r}}. \qquad (12)$$

If we separate the closed lines of integrated differential elements into two path integrals, we can formulate the R^{-2} Ampèrian long-range attractive force between two open and closed circuits:

$$\mathbf{F} = -\frac{\mu_0}{4\pi}\int_0^{\mathbf{s}_j}\int_0^{\mathbf{s}_i}\frac{I_i d\mathbf{s}_i \cdot I_j d\mathbf{s}_j}{r^2}\hat{\mathbf{r}}. \tag{13}$$

$$\mathbf{F} = -\frac{\mu_0}{4\pi}\int_{C_1 0}^{\mathbf{s}_j}\int_{C_2 0}^{\mathbf{s}_j}\frac{I_i d\mathbf{s}_i \cdot I_j d\mathbf{s}_j}{r^2}\hat{\mathbf{r}}. \tag{14}$$

The Lorentz force specifically deals with transverse effects. Here, we simply intend to draw attention to the possible role of Ampèrian components and effects coexisting with the transverse wave effects well-described by Maxwell equations, in relation to the general dynamics of space plasmas [17]. Such pervasive plasma structures in space by nature respond to electromagnetic forces to form tremendously vast networks of current-conducting filaments.

In applying to their core physics Ampère's pre-field electrodynamic principles, we propose that their formation, morphology, and interaction bring into play not only long-range attractive (long-range R^{-1} attraction) and short-range repulsive (short-range R^{-3} repulsion) forces, but also non-transversal distribution of ponderomotive and electromotive forces (involving Ampèrian fundamental force interactions between two electric currents at all size scales):

<u>Component (1)</u>

$$\mathbf{F}_{ji}(I_{zi}, I_{zj}) = \frac{\mu_0 I_{zi} I_{zj}}{2\pi R}\hat{\mathbf{r}}. \tag{15}$$

=> Long-range attractive Biot-Savart's transversal force.

This verifies the fact that the electric force is an attractive force in the direction of the positive *z*-axis.

<u>Component (2)</u>

$$\mathbf{F}_{\mathrm{ji}}(I_{\theta\mathrm{i}}, I_{\theta\mathrm{j}}) = \frac{\mu_0 I_{\mathrm{zi}} I_{\mathrm{zj}} \pi r}{4\pi R}\left[(\sin\theta)\hat{\mathbf{r}} - (2\cos\theta)\hat{\boldsymbol{\theta}}\right]. \tag{16}$$

=> Short-range repulsive Biot-Savart’s transversal force.

<u>Component (3)</u>

$$\mathbf{F}_{\mathrm{ji}} = \frac{\mu_0 I_{\mathrm{i}} I_{\mathrm{j}} d\mathbf{s}_{\mathrm{i}} d\mathbf{s}_{\mathrm{j}} \hat{\mathbf{r}}_{\mathrm{ji}}}{4\pi}\frac{1}{r^2}\left(2\sin\alpha\sin\beta\cos\gamma + \cos\alpha\cos\beta\right). \tag{17}$$

$$\mathbf{F}_{\mathrm{ji}} = \frac{\mu_0 I_{\mathrm{i}} I_{\mathrm{j}}}{4\pi r_{\mathrm{ji}}^{\;2}}\left[3\left(d\mathbf{s}_{\mathrm{i}} \cdot \hat{\mathbf{r}}_{\mathrm{ji}}\right)\left(d\mathbf{s}_{\mathrm{j}} \cdot \hat{\mathbf{r}}_{\mathrm{ji}}\right) - 2\left(d\mathbf{s}_{\mathrm{i}} \cdot d\mathbf{s}_{\mathrm{j}}\right)\hat{\mathbf{r}}_{\mathrm{ji}}\right]. \tag{18}$$

$$\mathbf{F}_{\mathrm{ji}} = \frac{\mu_0 I_{\mathrm{i}} I_{\mathrm{j}}}{4\pi}\oint\oint\frac{1}{r_{\mathrm{ji}}^{\;2}}\left[\begin{array}{l} 3\left(\frac{dx_{\mathrm{i}}}{d\mathbf{s}_{\mathrm{i}}}\hat{\mathbf{r}}_x + \frac{dy_{\mathrm{i}}}{d\mathbf{s}_{\mathrm{i}}}\hat{\mathbf{r}}_y + \frac{dz_{\mathrm{i}}}{d\mathbf{s}_{\mathrm{i}}}\hat{\mathbf{r}}_z \cdot \hat{\mathbf{r}}_{\mathrm{ji}}\right)\left(\frac{dx_{\mathrm{j}}}{d\mathbf{s}_{\mathrm{j}}}\hat{\mathbf{r}}_x + \frac{dy_{\mathrm{j}}}{d\mathbf{s}_{\mathrm{j}}}\hat{\mathbf{r}}_y + \frac{dz_{\mathrm{j}}}{d\mathbf{s}_{\mathrm{j}}}\hat{\mathbf{r}}_z \cdot \hat{\mathbf{r}}_{\mathrm{ji}}\right) \\ -2\left(\frac{dx_{\mathrm{i}}}{d\mathbf{s}_{\mathrm{i}}}\hat{\mathbf{r}}_x + \frac{dy_{\mathrm{i}}}{d\mathbf{s}_{\mathrm{i}}}\hat{\mathbf{r}}_y + \frac{dz_{\mathrm{i}}}{d\mathbf{s}_{\mathrm{i}}}\hat{\mathbf{r}}_z \cdot \frac{dx_{\mathrm{j}}}{d\mathbf{s}_{\mathrm{j}}}\hat{\mathbf{r}}_x + \frac{dy_{\mathrm{j}}}{d\mathbf{s}_{\mathrm{j}}}\hat{\mathbf{r}}_y + \frac{dz_{\mathrm{j}}}{d\mathbf{s}_{\mathrm{j}}}\hat{\mathbf{r}}_z\right) \end{array}\right]\hat{\mathbf{r}}_{\mathrm{ji}} d\mathbf{s}_{\mathrm{i}} d\mathbf{s}_{\mathrm{j}}. \tag{19}$$

=> Ampère’s angular and distance-dependent action and reaction mechanical force law accounting for the distributions of ponderomotive and electromotive interactions irreducible to Lorentzian effects. We express it as closed integrated to suggest its application on and expansion through all size scales. Decomposed into interacting current elements, our assumption consists in recomposing it through integration of its components to theoretically account for the distribution of its non-Lorentzian force effects at any arbitrary scale, including around cosmic-sized electric circuits.

Conclusion

Could the total force action in dynamic, electrically active plasma structures in space feature various distributions and types of forces and torques? Our own research, which seems to find its natural place within the Electric Universe hypothesis, seeks to corroborate the existence of Ampèrian angular-dependent forces in large macroscopic filamentary strands of astrophysical current-carrying plasma circuits, according to which Lorentzian force effects governed by the Biot-Savart law are not the only players in large-scale electrodynamic theory.

To give a theoretically quantitative method illustrating our hypothesis, we propose to treat the volume elements of current differentially used by Ampère as basis of an electrodynamics of mutual action of electric currents at all size scales. Assuming, on the basis of coherent scalability in an Electric Universe, that these elements could be upscaled and conversely integrated to calculate the effect and distribution of ponderomotive and electromotive forces between two arbitrary circuits under the conditions of long-range and short-range attraction dynamics in space, we theorize a model of Ampèrian force action of electric currents for filamentary plasma circuits in space, the details of which we hope to present and further discuss in the future.

References

[1] Expounded on at EU2016, see here from 41:43 to 51:05.

[2] In *J. of the AIEE*, 1926, **45**, 5, pp. 453-453.

[3] *A new system of electromagnetic forces needed*, in *J. of the AIEE*, 1922, **41**, 4, pp. 305-307.

[4] In *Trans. of the AIEE*, 1923, **42**, pp. 311-340.

[5] Hering's experiment consisted of a single rectangular shape circuit made of condensed wire metal elements, with the circuit's two end legs immersed in a pool of mercury. When a very high current density is supplied to the pool connected to the circuit from a power source, classically unexpected force effects ensue.

[6] The Exploding Wire Method.

[7] See especially his *First Indication of Ampere Tension in Solid Electric Conductors*, in *Phys. Lett. A*, 1983, **97**, pp. 253-255.

[8] In *J. Phys. D: Appl. Phys.*, January 1999, **30**, 22, p. 3131.

[9] Which he recapped in *Electromagnetic Jet-propulsion in the Direction of Current Flow*, in *Nature*, 1982, **295**, pp. 311-312.

[10] See, for example, his *Application of Ampere's Force Law to Railgun Accelerators*, in *J. Appl. Phys.*, 1982, **53**, p. 6642 and *Amperian recoil and the efficiency of railguns*, in *J. Appl. Phys.*, 1987, **62**, pp. 3006-3009.

[11] Graneau Peter, *Ampere-Neumann Electrodynamics of Metals*, Hadronic Press, Inc., second edition, p. 132.

[12] Graneau Peter, *Ampère Tension in Electric Conductors*, in *IEEE Trans. on Magnetics*, March 1984, **20**, 2, pp. 444-455.

[13] *Ampere-Neumann Electrodynamics of Metals*, pp. 138-141.

[14] Such experiments, which we cannot here further describe, have been conceived and set up to arrive at unambiguous observations of net longitudinal force effects using significantly milder currents.

[15] In *Phys. Lett. A*, 1985, **111**, 6, pp. 315-316.

[16] By reason of his interest in both Ampère's electrodynamics and the Electric Universe theory, the author himself has advanced and submitted this line of research to be one worth exploring.

[17] Further developments pertaining to this model will be discussed in a future paper.

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