On a Relativistic Voltage Limit and its Implications

by Chris Granger

Abstract

An effective tool for analyzing correlations in disparate dynamical systems is the analogical model; such models can provide insights otherwise unrealistic to obtain. Analogical analysis can be done with any suitably defined set of object theories, but the challenge is in discovering models capable of yielding physical insights. Here I show such an analogical model between momentum and charge; analysis suggests voltage is limited to the speed of light and that capacitive charge becomes unbounded with voltage. If confirmed, the ability to manipulate substantial mass-energy appears possible via electrodynamic means. Possible connections with dark energy and dark matter, vacuum energy, and the weak field are discussed in the supplementary information (SI).

Background

In this paper, analogical notation ':' and '::' are symbols for "is to" and "as" respectively; I have introduced an additional notation ':=:' meaning "is analogous to". For example, (A+B):=:(C+D) reads "A+B is analogous to C+D." In general, symbolic language is avoided for readability.

I've introduced a postulate for the primary conditions in evaluating a formal analog; these are: analogical reversibility, mathematical identity, dimensional consistency, and correlative dynamical behavior; I refer to this as the "*Analogical Equivalency Postulate*" (A.E.P.) (SI: "Analogical Equivalency Postulate"). Reasonable analogical models can be achieved with partial equivalency; the analog here is maximally equivalent.

Both symbols and units are required to properly show analogical equivalence; symbols are represented by their conventional abbreviations in *italics,* whereas units are via SI convention in normal type. The analog itself is dimensionally separable in space and only requires signed scalars for 1-d momentum representation; vector notation is avoided for clarity of the analog.

In classical physics study, charge q and mass m are often taken as analogs; similarly, springs and capacitors are sometimes treated as analogs. I refer the reader to my supplementary information (SI: "Suitable Analogs") as to why such analogs are non-conforming, and (while often useful) are unsuitable for our purposes here.

The analog herein is developed based on three conservation laws: conservation of energy, conservation of momentum, and conservation of charge; no arbitrary constants are employed and all terms can be expressed in base units available in either the target or object model.

Conservation of energy and momentum suggest a strong formal analog between charge Q in Coulombs (C) and momentum p (kg·m/s) where

$$Q :=: p \tag{1}$$

and

$$p=mv \tag{2}$$

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where m is mass (kg) and v is velocity (m/s), and more precisely where charge Q in this context represents the $-Q$ and $+Q$ charged plates of a capacitor

$$Q=CV \tag{3}$$

C is the capacitance in farads (F) and V is voltage in volts (V). My analogical model equates this charge CV to moving mass

$$CV :=: mv \tag{4}$$

in which both voltage and velocity represent dynamical conformity as an energy potential with respect to a relative reference, whereby the motion of their constituents (charge carriers and momentum carriers) can perform work

energy of mass:relative velocity :: energy of capacitance:relative potential (voltage) (5)

Classically, the energy present in moving mass at some relative velocity v is

$$U=mv^2/2 \tag{6}$$

and the energy present in capacitance charged to voltage V is

$$U=CV^2/2 \tag{7}$$

where energy U is in joules (J), and thus by analog:

$$v :=: V \tag{8}$$

and

$$m :=: C \tag{9}$$

Importantly, there are no proportionality constants aside from the properties themselves and both are charge sign indifferent with respect to their ability do work. Consider momentum conservation

$$m_1v_1=m_2v_2 \tag{10}$$

then via analog substitutions $m:=:C$ and $v:=:V$ we discover

$$C_1V_1=C_2V_2 \tag{11}$$

which is the known property of charge conservation; recognize that this was derived from momentum conservation via the analog. Charge Q and momentum p are signed within their respective domains, whereas capacitance C and mass m are unsigned; both mass and capacitance have no net charge imbalance. Recognize:

$$U=mv^2/2=(mv)v/2=pv/2 \tag{12}$$

$$U=CV^2/2=(CV)V/2=QV/2 \tag{13}$$

Note from comparing (12) and (13) that charge Q is analogous to momentum p; $Q :=: p$ presents an appropriate dynamical relation where both obey conservation laws based on their fundamental storage carriers, that is

(conservation of momentum:$m_1v_1=m_2v_2$*) :: (conservation of charge:*$C_1V_1=C_2V_2$*)* (14)

and with respect to energy conservation,

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momentum:energy converted in favor of momentum conservation ::

charge:energy converted in favor of charge conservation (15)

Each demonstrates a type of inertia within their respective domain. From Newtons 2nd law,

$$F=ma=m(dv/dt) \tag{16}$$

where F is force in newtons (N) and a is acceleration (m/s^2), and t is time (s). That is, mass resists a change in velocity when subject to a *force.* From the charge equation for a capacitor,

$$i=C(dV/dt), \tag{17}$$

where i is current in amperes (A), capacitance resists a change in voltage when subject to a *current* (SI: "Tertiary *F:=i* Correlations"). We recognize that the analog holds where

$$F:=:i \tag{18}$$

Alternatively, we can arrive at the above via taking the momentum and charge derivatives directly and performing the analog substitution, since

$$p=mv \rightarrow dp/dt=m(dv/dt) \rightarrow F=m(dv/dt) \tag{19}$$

$$Q=CV \rightarrow dQ/dt=C(dV/dt) \rightarrow i=C(dV/dt) \tag{20}$$

The analog allows us to derive either model. Current i in amperes (A) should resolve to units of force within its own domain (that is, without an analog substitution) given rigorous formalism; this is further expected because the formal definition of ampere is a force (SI: "Ampere..."). If dimensional analysis can illustrate a unit correlation of amperes (A) as kg·m/s^2 and volts (V) as m/s then the systems suggests an intrinsic physical connection. Consider the definition of the volt (in SI units):

$$\mathrm{V=W/A = J/(A\cdot s) = (N\cdot m)/(A\cdot s) = ((kg\cdot m/s^2)\cdot m)/(A\cdot s) = (kg\cdot m^2)/(A\cdot s^3)} \tag{21}$$

$$\mathrm{V=(kg\cdot m^2)/(A\cdot s^3)} \tag{22}$$

then

$$\mathrm{A\cdot V = (kg\cdot m^2)/(s^3)} \tag{23}$$

and regrouping terms:

$$\mathrm{A\cdot V = (kg\cdot m/s^2) \cdot (m/s)} \tag{24}$$

We may consider other groupings, but we know that current is defined as a force so we expect to find a force term. We also see the velocity term emerge, conforming to the analog. A correlation exists at the *unit level.* Amperes A=(kg·m/s^2) as force and volts V=(m/s) as velocity, are present here as identically used throughout the analog. Further, by definition (3)

$$Q=CV \tag{25}$$

and from the definition of current i in amperes (A)

$$i = Q/t = \mathrm{A = Coulombs/second} \tag{26}$$

$$Q=it=\mathrm{A\cdot s = Coulombs} \tag{27}$$

then assuming the unit form of (24)

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$$\mathrm{A} = \mathrm{kg \cdot m/s^2} \tag{28}$$

the resolved SI units of charge are

$$Q = (\mathrm{kg \cdot m/s^2}) \cdot \mathrm{s} \tag{29}$$

$$Q = \mathrm{kg \cdot m/s} \tag{30}$$

which is identical to momentum (consistent with the analog), and again assuming the unit form (24)

$$V = \mathrm{m/s} \tag{31}$$

then in unit context from (30)

$$Q = CV = \mathrm{kg \cdot m/s} \tag{32}$$

and resolving capacitance in unit context

$$C = \mathrm{kg} \tag{33}$$

Capacitance (C) resolves to units of kg in this context, as used identically throughout the analog.

If certain properties do not become physically unwrapped they are still dimensionally consistent and can be subject to similar physical constraints. We can reasonably hypothesize that these properties may be different manifestations of similar phenomena.

Therefore we recognize a maximally equivalent analog by the A.E.P.: it is mathematically identical, dynamical behavior is correlative, it holds reversibly where momentum and energy conservation are implicit (we can derive either from the respective analog) and dimensional analysis is consistent (the units match).

Hypothesis on a Relativistic Charge-Momentum Analog

[SR] is special relativity, [CM] is the classical mechanics subset limited to the [SR] domain, [CC] is the capacitive charge model subset, [CR] is the relativistic capacitive charge model subset.

[CM], [SR], [CC] are known formal theories; [CR] is a unknown formal theory.

[CM] :=: [CC] is maximally equivalent by the A.E.P.

[CM] represents an approximation to [SR] over the domain [X] given some error [E], where [SR] represents the naturally preferred theory. Since [CM]:=:[CC], we expect [CC] to represent an approximation to a corresponding [CR] that represents the naturally preferred theory.

Analysis between [CM] and [SR] yield a set of differences [SR]-[CM]=[D_m] over all [X]. These differences [D_m] represent corrections to [CM], whereby [CM]+[D_m]=[SR].

Given maximally equivalent analogical systems where [CM] :=: [CC] over all [X], then let [CM]+[D_m] :=: [CC]+[D_c], where [D_c] represents a correction set; it follows that [D_m] :=: [D_c] such that [CC] will require the corrections [D_c] for the analog to remain valid over [X]. In conjunction then, let [CR]=[CC]+[D_c]; since [SR]=[CM]+[D_m] the analog [SR]:=:[CR] exists by definition.

It follows that the charge-momentum analog applies to the relativistic model barring falsification. That is, for constant voltage reference frames, electrical potential difference is always less than the speed of

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light c (2.99792458×10^8 m/s):

$$V < c \tag{34}$$

Physical justification is suggested in the unit identities of equation (24). Taking SR as valid theory, the velocity (m/s) term on the right-hand side of (24) would be implicitly limited to the speed of light c due to the explicit mass (kg) term.

SR momentum is: $p=m_0v/(1-(v^2/c^2))^{1/2}$. By analog substitution, to conserve charge in all constant voltage frames thus requires:

$$Q=C_0V/(1-(V^2/c^2))^{1/2} \tag{35}$$

and for "relativistic capacitance" with voltage

$$C'=C_0/(1-(V^2/c^2))^{1/2} \tag{36}$$

and, possibly time dilation in the capacitor frame

$$t'=t(1-(V^2/c^2))^{1/2} \tag{37}$$

and energy

$$U_t=C_0c^2/(1-(V^2/c^2))^{1/2} \tag{38}$$

$$U_c=C_0c^2/(1-(V^2/c^2))^{1/2}- C_0c^2 \tag{39}$$

$$U_0=C_0c^2 \tag{40}$$

By analogy, voltage addition is expected to follow a special relativistic relation, for example

$$V=(V_1+V_2)/(1+V_1V_2/c^2) \tag{41}$$

which, for reasonably low potentials would reduce to a summation.

Other suitable analog substitutions may be similarly applied across the relativistic domain.

Discussion

An inference arising from the analog is the possible capacitive rest energy suggested in (40)

$$U=C_0c^2 \tag{42}$$

which represents the energy of a capacitor at zero voltage. If such energy exists, it is intrinsic to capacitance itself and thus not locally bound but universal (any conductor or non-conductor capable of possessing charge has a self-capacitance with respect to the universe). There are possible connections with dark energy and vacuum energy; calculations indicate the universal capacitive rest energy density matches the accepted cosmological dark energy density (SI: "Dark Energy and Capacitive Rest Energy").

Voltage constraints may be due to the same property of the SR universe which limits the speed of mass; this may be related to the weak field interaction (SI: "Possible Weak Field Correlation").

One may ask if there are other suitable analogs; while possible, none have been identified save for inductance which is the capacitive dual (SI: "Suitable Analogs"). Doing this requires transforming to a constant current frame; relativity can reduce this to the capacitive model. As the field dual it may have

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use; for instance, one might interpret a portion of the rest energy as inductive (L_0) in a moving inertial frame rather than transform to a rest frame. It is the expectation that this will be a matter of mathematical convenience.

The analog was presented in the canonical context of static fields to provide a clear description. I have expressed my hypothesis via analog to SR and thus specified a constant voltage frame; the behavior for frames with a voltage gradient is expected to behave analogous to general relativity (GR) but such analogical formalism will need to address any arbitrary constants; a complete description would include motion of charges and thus incorporate retarded potentials.

The supplementary information (SI) contains an extended discussion with calculations, including speculation on dark energy and dark matter, vacuum energy, applications, possible experimental tests, and predictions.

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Supplementary Information (SI)

Introduction to the SI

Additional information, predictions, and insights are included. Calculations are in discussion format; they are high level and not intended to be overtly formal or cover every facet of the hypothesis, its implications, or its subtleties.

A Note on References

My primary hypothesis is data independent, based on fundamental principles and well established theory. In the case of this supplementary discussion, I have included source information inline where applicable. Please refer to the author contact information if you have any questions in connection with this SI.

Analogical Equivalency Postulate

This postulate specifies conditions for determining equivalent analogical models; it does not prove analogical truth, but suggests probability of analogical truth. For readability, I have written this in natural language rather than symbolic formalism.

The first three conditions must hold for all mathematically strict analogs of systems or system subsets over some selected domain; the forth suggests equivalent physical behavior within a specified principle, and the fifth is for systems which have multiple object definitions.

Conditions:

1. Analogical Reversibility:

 if (A:=:B) and (f(A,x,y,z,...)=Q) and (g(B,x,y,z,...)=P), then (f(B,x,y,z,...)=P) and (g(A,x,y,z,...)=Q)

2. Mathematical Identity:

 if f(x,y,z,...) :=: g(x,y,z,...), then f(x,y,z,...) = g(x,y,z,...)

3. Dimensional Consistency:

 if X is a 'physical dimension', then

 if (A is X) and (A:=:B), then (B is X)

4. Dynamical Correlation:

 if P and Q are 'physical behaviors of principle', then

 if (((A is to P(A)) as (B is to Q(B))) and (A:=:B)), then (P is congruent to Q)

5. Reduction:

 if (A=B) and (A=P) and (B=Q), then ((A=P) or (A=Q)) and ((B=P) or (B=Q))

Note that the first three conditions are sufficient for strict equivalence, while the fourth is either a

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confirmation (maximally equivalent) or prediction and depends on the definition of physical behavior of principle; those principles include conservation and relative behavior.

In the fifth condition, a mode indicates a physical quantity arriving from a particular equation; this clarifies identity in certain physical models where multiple equivalent modes are available but certain modes may or may not be obfuscated.

It is possible to apply local equivalence (that is, if a subset of the analog is selected, only a limited set of the possible equations in the subset must also be analogous). In the context of this discussion, we only consider strict analogs (that is, global equivalence) within the subset.

As a note, the common "charge-mass" analog of classical physics study fails for strict equivalence unless one creates a system of analogous constants and specifically limits the subset; such a system cannot extend to the canonical SR analog since no such constants exist in the model.

Suitable Analogs

We recognize that if a property under question fails to be suitably analogous with respect to the property under evaluation, the analog fails for that condition. Not every condition of the object must be reversible with the target for the analog to be useful within some context; however, the strength of the analog can be evaluated. In classical physics study, mass m and charge q are often taken as analogs:

$$m :=: q \qquad \text{(S.01)}$$

within the domains of classical mechanics and classical electromagnetism, respectively. This analog seems appropriate since certain equations match *in form*, for example Newton's law of universal gravitation

$$F_g=Gm_1m_2/r^2, \qquad \text{(S.02)}$$

and the Coulomb electrostatic force equation

$$F_e=kq_1q_2/r^2, \qquad \text{(S.03)}$$

are virtually identical. However, the respective proportionality constants G and k are not implicit to properties within either equation; they can *arbitrarily* force dimensional consistency and do not themselves share consistency. Any function which modifies mass m or charge q may be absorbed into the proportionality constants, breaking analog symmetry. Thus, while these equations may suggest a similar fundamental phenomena they do not represent a rigorous formal analog.

We can specify an analog where $G :=: k$ and repeat the entire process for the models in the subset, thereby providing another analog which may be partially equivalent. But, if one makes $G :=: k$ they are then limited the subset which invokes G and k, and may also violate dimensional consistency. Alternatively, one may try to normalize the constants so that, for example, $G=k_r$, where $k_n=kn$ and n is in terms of V or other intrinsic element, but this will result in broken symmetry with the static field equations.

My analogical model is based on the strength of conservation principles, in conformance to that set of identical analogs which present no arbitrary forcing functions outside of the analogical elements; as such, it represents a consistent set.

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Tertiary *F:=i* Correlations

This is a further demonstration of unit consistency for *F:=:i*; it goes beyond the SR model and is supportive, but not required for the hypothesis. Note that:

$$F{:}m(dv/dt) :: i{:}C(dV/dt) \quad \text{(S.04)}$$

$$F=m(dv/dt) :=: i=C(dV/dt) \quad \text{(S.05)}$$

Mass and capacitance match in the analog; velocity and voltage match. As before, by continuing analog, *i* (current) and *F* (force) also correlate, that is

$$F :=: i \quad \text{(S.06)}$$

dynamically, we recognize that neither are relative quantities, two equal but opposing forces result in zero net force, two equal but opposing currents result in zero net current, and superposition applies to both current and force. Further, consider one definition of work:

$$U=Fs \quad \text{(S.07)}$$

where *s* is distance in meters (m) then

$$s = vt \rightarrow U=Fvt, \quad \text{(S.08)}$$

where U is the work (energy) in joules. By analog, if

$$v :=: V \quad \text{(S.09)}$$

and

$$F :=: i, \quad \text{(S.10)}$$

then by analog substitution with (S.08) (including dimensional analysis)

$$i\,Vt = U \rightarrow \mathrm{A\cdot(J/(A\cdot s))\cdot s = J} \quad \text{(S.11)}$$

which dimensionally holds. Given (S.10) (that is, *F:=:i*)*, force* and *current* should resolve to the same dimensional units for a strict analog. From electrodynamics we know that force on a conductor is *F=i (l x B)*, where *l* is conductor length and *B* is a magnetic field. Given two conductors carrying a current, the *l x B* term becomes implicit (as current gives rise to a magnetic field) resulting simply in a force between the conductors. Identically, the formal definition of the ampere is based on the *force* generated between two parallel current carrying wires (SI: "Ampere: Formal Definition"). In physical terms, electric current manifests as a force in the mechanical domain; in this regard, they are equivalent.

Tertiary *F:=:i* Correlations with Equivalency Constant

As current *i* appears in the equations, such relationships suggest that electrical resistance *R* may have a reverse analog in some domains; this is not necessary, but it is supportive of the hypothesis. Indeed, resistance appears as time in linear combination with the energy carrier:

$$V = iR \rightarrow V = (CdV/dt)R \quad \text{(S.12)}$$

By analog:

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$$F :=: i \tag{S.13}$$

and by analogous substitution with an unknown analog term *b*

$$R := : b \tag{S.14}$$

$$v=Fb \;\rightarrow\; v=(ma)(b) \tag{S.15}$$

then by inspection

$$v=(ma)((1/m)t)=(ma)(t/m) \tag{S.16}$$

or

$$b=t/m \tag{S.17}$$

an noted, to comprise a strong analog any constant must be in terms of some intrinsic properties of the analog itself; we have satisfied this condition. By analog substitution:

$$R :=: b;\; b=t/m \tag{S.18}$$

$$R :=: (t/m) \tag{S.19}$$

and mass correlates with capacitance in the analog as $m :=: C$, thus

$$R = t/C \tag{S.20}$$

$$t=RC \tag{S.21}$$

This is the well known time constant, in proper units of seconds. Time is merely conjoined linearly with the energy storage medium. Note that the units and physical manifestations of the objects are correlative:

$$i^2R=Watts=energy/time=U/t=\text{J/s} \tag{S.22}$$

then, by direct analog substitution $F :=: i$

$$F^2b=U/t;\; b=t/m \tag{S.23}$$

$$(ma)^2(t/m) = ma^2t = (ma)(at) = Fv \tag{S.24}$$

$$Fv=Fs/t=U/t=\text{J/s} \tag{S.25}$$

again, units are consistent and the analog holds.

Analogically Reproducible Modes

A strong case for the charge-momentum analog demonstrating rigorous equivalence is that it exhibits reversibility within physically reproducible modes given the classical domain. For instance, (classically) capacitors add in parallel at a constant voltage:

$$C_t=C_1+C_2+C_2+... \tag{S.26}$$

as does mass at a constant velocity:

$$m_t=m_1+m_2+m_3+... \tag{S.27}$$

When we connect capacitors in series, we alter the potential frame for each subsequent capacitor. To be

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analogically consistent, we can only consider a single potential if we recognize that we have *physically* removed capacitance from the system via the series connection. For example, if we have two 1 F capacitors each at 2 V we have a charge of 4 C. If we connect them in series, we physically create a 0.5 F capacitor at 4 V. This new capacitor has a charge of only 2 C; we have *physically removed* 2 C of charge from the system and increased the voltage to 4 V – we must recognize this revised charge if we are to maintain charge conservation.

Consider two 1 kg objects each at 2 m/s in a 1-d frame (momentum 4 kg·m/s) we create the analogous system by arranging these objects as a 0.5 kg mass at 4 m/s. But to do this, we must *physically remove* 0.5 kg from the system and increase the velocity to 4 m/s. Thus, we removed 2 units of momentum from the system, just as we removed 2 C with charge; the analog holds reversibly.

A conforming analog should hold with the most formal object theory. If in a mathematically identical analog a correction is made to one model where $A \neq B$, then we would expect to find $A \neq B$ in the analogous condition. Otherwise, the suggestion that we started with two mathematically symmetrical systems that demonstrably held physically would likely be false. As such, if an object correction that better approximated the physical world dissolved the identity, it would mean that the identity only held reversibly for the object's *incorrect* model, which would be quite unnatural and improbable.

Tertiary Observation Regarding Possible Extended Analog

This is not a necessary condition for the model under analysis; it presents a condition outside of the constant frame domains being discussed for the SR analog, but it is an interesting observation. Consider energy in the charged capacitor:

$$U=Fd=CV^2/2 \tag{S.28}$$

and thus,

$$F=CV^2/(2d) \tag{S.29}$$

we recognize that from the definition of mechanical energy we can say

$$U=Fd=mv^2/2, \tag{S.30}$$

and that

$$F=mv^2/(2d). \tag{S.31}$$

This relationship *form* also suggests centripetal force when given a rotating reference. We are not considering rotating frames in the context of SR, so such is not a present model requirement. However, it is interesting to note via analog

$$i=CV^2/(2d) \tag{S.32}$$

suggesting that in a reference frame which exhibits the analog of centripetal acceleration, meaning some manifestation of a constant voltage gradient, a current develops across the plates that is proportional to the plate voltage and distance; we would expect such type of behavior. Similarly given the inertial domain, a charged capacitor moving relative to a reference and perpendicular to its field would exhibit additional force between its plates due to the induced B field; this motion of charge is equivalent to a current. We recognize force in the definition of current; the relativistic effect is apparent through the analog.

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Dimensional Representation vs Dimensional Analysis

In the analog I do not differentiate scalars and vectors; these are dimensional representations, not analogous properties (such as conservation principles) or dimensional analysis (such as unit identities) and thus not relevant in this context.

Momentum is an example. We can constrain motion to one dimension, effectively resulting in signed scalar; SR properties hold and so does the charge analog. We can then select a set of signed scalars to represent momentum in *n*-dimensional space; each member being analogous to any corresponding charge analog; this is a dimensional representation. It is important not to confuse such dimensional representations with inherent physical properties and dimensional analysis.

Cosmological and Quantum Considerations

Dark Energy and Capacitive Rest Energy

Capacitive rest energy could account for dark energy; this also could (by extension) suggest that dark energy and vacuum energy are specific manifestations of the same field.

The current WMAP data (http://map.gsfc.nasa.gov/) indicates a universal mean density at $\approx 9.9 \times 10^{-27}$ kg/m^3; the dark energy component being ≈72% is roughly

$$\approx 7.1 \times 10^{-27}\ \text{kg/m}^3\text{, or } 6.4 \times 10^{-10}\ \text{J/m}^3. \qquad \text{(S.33)}$$

By conjecture, the total capacitive rest energy is a universal field that is a function of anything that can carry charge. It is expected to comprise the agglomerate of homogeneously distributed self-capacitive objects, primarily hydrogen nuclei, which comprise nearly all of the intergalactic space.

Note that condensed matter would have an aggregate miniscule capacitance. For instance, if we consider the sun with radius $\approx 7 \times 10^8$ m and its capacitance to be the self-capacitance then

$$Cc^2 = 4\pi\varepsilon_0 Rc^2 \approx 0.078c^2 \text{ --> } Uc{,}rest \approx 7 \times 10^{15}\ \text{kg} \qquad \text{(S.34)}$$

Since the sun's mass is $\approx 2 \times 10^{30}$ kg this capacitive rest energy (S.34) is a trivial amount (roughly a billion times smaller than earth). Clearly the total dark energy cannot be the capacitive rest energy of condensed matter at such density; stars and dense gases are thus eliminated from consideration.

Warm-hot plasma is expected to comprise roughly 50% of the total baryonic mass and practically all the universal hydrogen. With the recent discovery by Chandra of a hot plasma halo around our galaxy roughly the same mass as our galaxy and $\sim 10^{-3}$ times as dense (http://www.nasa.gov/mission_pages/chandra/news/H-12-331.html) we will make the assumption here that our galaxy is is structured similar to others (that is, stars, gas, halo) and that roughly half (50%) of the baryons are in this form.

We can estimate the capacitance of the individual protons and electrons with a classical approximation

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for a self-capacitive sphere:

$$C_p=4\pi\varepsilon_0 R_p=4\pi\varepsilon_0(0.8768 \text{ x } 10^{-15}) = 9.76 \text{ x } 10^{-26} \text{ F} \quad (S.35)$$
$$C_e=4\pi\varepsilon_0 R_e=4\pi\varepsilon_0(\sim 10^{-21}) = 1.1 \text{ x } 10^{-31} \text{ F} \quad (S.36)$$

We recognize that the self-capacitance of an electron is negligible. The overall average density of the hydrogen is estimated via the mean density of 9.9 x 10^{-27} kg/m^3, times the 4.6% estimated to be normal matter, of which 50% is estimated to be gas.

$$\textit{density of gaseous protons} \approx 0.046 \text{ x } 0.50 \text{ x } (9.9 \text{ x } 10^{-27}) \approx (2.28 \text{ x } 10^{-28} \text{ kg/m}^3) \quad (S.37)$$
$$(2.28 \text{ x } 10^{-28} \text{ kg/m}^3)/(1.67 \text{ x } 10^{-27} \text{ kg/proton}) \approx 0.137 \text{ protons/m}^3 \quad (S.38)$$

We now need to calculate a participation value. We know that dense gases are eliminated (<1% participation) but we don't know the limit function; we also know that a single, isolated hydrogen nuclei would give 100% participation, but don't know how rarefied the plasma must be for this to occur. Clearly, there is a density function that covers the range. But, given the difficulty in ascertaining a curve from known data, I've opted to allow the total 0% - 100% participation range, meaning a factor of 0.50 +/-0.50, or

$$(0.50)(0.137 \text{ protons/m}^3) \approx 0.069 \text{ +/-}0.069 \text{ protons/m}^3 \quad (S.39)$$

Certainly, the extremes (that is, 0% or 100%) are unrealistic. We could reduce this margin with reasonable assumptions, but for this treatment we will allow the uncertainty; our goal here is to evaluate if the result is close enough to warrant further investigation. We thus have a capacitance density of

$$C/\text{m}^3 \approx (9.76\text{x}10^{-26})(0.069 \text{ protons/m}^3) \text{ F/m\^{}3} \quad (S.40)$$
$$C/\text{m}^3 \approx 6.7 \text{ x } 10^{-27} \text{ F/m}^3 \quad (S.41)$$

or

$$U/\text{m}^3 \approx Cc^2/\text{m}^3 \approx 6.0 \text{ x } 10^{-10} \text{ J/m}^3 \quad (S.42)$$

$$\approx 6.7 \text{ x } 10^{-27} \text{ +/-}(6.7 \text{ x } 10^{-27}) \text{ kg/m}^3 \quad (S.43)$$

This estimated capacitive energy density is virtually identical to the estimated dark energy density by WMAP; the uncertainty must be taken with caution because we made no assumptions to limit the range extremes.

We may expect minor differences in overall baryon percentage, gas percentage, and additional gas, but the initial plasma estimate should be accurate to within a factor of ≈2 based on the published data. This suggests that capacitive rest energy is the best candidate for dark energy, provided my hypothesis is valid.

Though I do not expect substantial deviation from the capacitance estimate, this is based on the assumption that plasma will behave in the fashion I've described; that is, a sufficiently rarefied plasma will demonstrate low capacitive coupling of its elements. If these assumptions hold, there is sufficient

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energy in the rest capacitance of the sparse universal medium to account for the dark energy, provided my primary hypothesis is not falsified.

Capacitive Rest Energy and Vacuum Energy Density

We might speculate that capacitive rest energy manifests from the quantum vacuum field. A naive estimate of maximum rest capacitance density can be found by estimating the capacitance density

$$C/\mathrm{m}^3=(\varepsilon_0 A/d)/(Ad)=(\varepsilon_0/d^2)) \qquad \text{(S.44)}$$

then allowing the minimum distance as the Planck length $d \approx 1.616 \times 10^{-35}$ m, we obtain

$$C/\mathrm{m}^3 \approx 3.39 \times 10^{58}\ \mathrm{F/m}^3 \qquad \text{(S.45)}$$

Then, ignoring any weak field interaction and suppression, we estimate the hypothetical maximum capacitive rest energy as

$$U/\mathrm{m}^3 \approx (3.39 \times 10^{58})\, c^2 \approx 3 \times 10^{75}\ \mathrm{J/m}^3 \qquad \text{(S.46)}$$

Recognize that this represents the *maximum* capacitive rest energy density considering the Planck length as the distance limit.

Note the similarities in the magnitude of this energy density with that of typical quantum vacuum field estimates ($\sim 10^{40}$ J/m^3 to $\sim 10^{112}$ J/m^3). This suggests a possible resolution to the "vacuum catastrophe" based on a shift in interpretation; further details are reserved for a later exposition.

Dark Matter Conjecture

The majority of dark matter (if such exists) is expected to comprise an undiscovered non-baryonic form of matter (expected to be a particle) that doesn't interact electromagnetically; it is not expected to be connected with dark energy or matter. But as I've shown, dark energy may be a field effect instigated by matter, and dark matter could be a related effect.

Evidence for non-baryonic dark matter suggests it only interacts gravitationally (and perhaps via the weak field). Ignoring the "matter" moniker, the photon field acts this way, and thus (barring discovery of an unknown particle) dark "matter" *could* be regions of sufficiently dense energy fields (i.e., "dark mass").

The proposed capacitive rest energy is spread out over the entire universe and is *mostly* homogeneous. In regions of sufficient gravity and temporal epochs this energy field will densify around massively gravitating structures. Given a sufficient volume, it will begin to coalesce into separate structures under its own gravitational influence; those structures will affect local matter. The *overall* dark energy density of the universe remains virtually unchanged, but that is not necessarily true in the local sense.

A star does not have sufficient mass (nor influence sufficient volume) to densify the sparse field to any

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appreciable degree, but a large structure like a galaxy does, and cluster more so; larger scale means greater mass-to-distance ratio, and the more dominant dark mass becomes.

While it is possible to estimate this effect, a simple calculation such as used for the universal dark energy is not applicable. This is because the density and composition of the gravitating material plus inter-coupling of the fields creates complex interactions. One way to simplify is to compare the estimated capacitance density ratios with that of the measured mass-to-light ratios. Though I can make a rough analytical estimate, it is better to build a numerical model; the degrees of freedom are substantial and such approximations could lead to inconclusive results.

If dark matter were this type of “dark mass” we would expect (in general) a greater detectable component near the larger scale structures. And, this is what we see. We wouldn't expect to find much (if any) dark matter in the local solar region (and we haven't detected it here). And similarly, we wouldn't detect much (if any) in the close stellar populations (and so far, we haven't detected it); the local gravitational potentials in these regions are simply not large enough to facilitate this.

As we move into larger regions we would expect to detect it, for instance between galaxies. Certainly, between close galaxy clusters we would expect copious amounts; because they are so massive gravity in the denser regions would be substantial. Sections would distort, coalesce, and separate, forming dark mass structures. Dark mass galaxies would not expect to exhibit dense cores (in general) due to this nature of formation (but possible if very massive). All of this is consistent with observation.

Dynamic effects could be complex because distribution and composition of the matter would effect the overall field, and the field would effect the matter distribution (perhaps even oscillating). If such fields separate, the lifespan profiles could look radically different; finding consistency might prove challenging.

Possible Weak Field Correlation

At very close ranges the charged weak interaction (mediated by W bosons) mixes with the electrostatic interaction; we might expect attenuation of the electric potential near this range as the probabilities shift towards the weak interaction (and photons couple with W bosons). Accordingly, if the weak field is connected to a light speed voltage limit, we might expect voltages to approach an appreciable fraction of light speed near this range.

The interaction range of the W boson (mass ≈ 80.4 GeV) can be estimated via the energy-time uncertainty principle:

$$R \approx \hbar c/(mc^2) \tag{S.47}$$

$$R \approx (6.582 \times 10^{-16})c/(80.4 \times 10^{9}\ \text{eV}) \tag{S.48}$$

$$R \approx 2.46 \times 10^{-18}\ \text{m} \tag{S.49}$$

R is the approximate interaction radius where weak field effects become substantial. This is a probabilistic estimate and since W bosons have a width (that is, an uncertainty in their mass) this figure represents a dynamic range near this locale.

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Real systems require at least two particles for an exchange force to manifest; semi-classically we can evaluate the electrostatic force between two particles outside the W boson interaction radius *R*. Assuming spherical fields, this disturbance separation distance is

$$d_s=2R \approx 4.92 \times 10^{-18}\ \text{m} \tag{S.50}$$

and the classical electrostatic force

$$F=kq_1q_2/d^2 \tag{S.51}$$

$$F=(9 \times 10^9)(1.602 \times 10^{-19})^2/(4.92 \times 10^{-18})^2 \tag{S.52}$$

$$F=9.54 \times 10^6\ \text{N} \tag{S.53}$$

then from the definition of voltage

$$V=U/q=Fd_s/q \tag{S.54}$$

and from the relative perspective of either charge at the computed distance

$$V=(9.54 \times 10^6)(4.92 \times 10^{-18})/1.602 \times 10^{-19} \tag{S.55}$$

$$V = 2.93 \times 10^8\ \text{V} \tag{S.56}$$

$$V \approx 0.98c \tag{S.57}$$

Indeed, the voltage approaches light speed near the W boson interaction range which suggests a possible weak field connection.

I do not prescribe overt significance to this calculation. Similar to the uncertainty computations for fundamental interactions or the classical electron radius, such provides a marker for qualitative insight. Still, the result is contextually relevant; near this range, the magnitude of the weak interaction is expected to exceed that of the electromagnetic interaction; being this close to the conjectured voltage limit suggests that noticeable effects would begin to occur prior to this point.

Note that we can consider the voltage in the context of capacitance but we must recognize that similar to computing a velocity of mass as exceeding *c* in classical mechanics, we could compute capacitor voltages exceeding *c*. As such, it does not make sense to estimate capacitance within this specific context without considering the analogous relativistic effects.

Analogical Considerations and Insights

Comment on Charge and Momentum Invariance

Based on the analog, as charge invariance is taken in the context of inertial frames, momentum invariance should be taken in the context of voltage frames. That is, momentum does not 'change' when subjected to a voltage, charge does not 'change' when subjected to a velocity. Note that C_0V becomes unbounded, just as in SR m_0v becomes unbounded. This is important, because the capacitive charge prediction cannot be tested with an inertial accelerator in the conventional sense.

Analytical Insight

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Based on the analysis, we expect behavior from the capacitive charge model to be analogous to the SR model. If the analog did *not* physically hold given the corrected SR model, the challenge would be to explain why. Such would be surprising (but insightful) if the analog only maintained reversibility with classical mechanics, which has been shown as a physically inconsistent model (that is, not naturally preferred).

The magnetic field is invoked for current to manifest as a force; this is a relativistic effect compatible with SR and the analog. SR is compatible with classical electrodynamics, and the analog already has basis in a Lorentz invariant theory via *F:=:i* as derived from analogous definitions; non-analogous behavior is improbable.

Fermion-Boson Qualitative Comment

I have not yet formalized this thought, so at the risk of making an analogical blunder, the basic principle follows the context of my presentation and is akin to this:

"Intrinsic mass represents the potential of the fermionic field, intrinsic capacitance represents the potential of the bosonic field; momentum represents the "inertia" of the fermionic field, charge represents the "inertia" of the bosonic field."

It's fairly self explanatory. Rest mass has energy, and this represents a potential of fermions. And, rest capacitance has energy, and this represents a potential of bosons. Accordingly, momentum is the "inertial" property of fermions, and charge is the "inertial" property of bosons.

As such, constant inertial frames are a behavior of fermions, whereas accelerations are an effect of bosons. And, constant voltage frames are a behavior of bosons, whereas voltage gradients are an effect of fermions.

Interpretations

In the case of matter, we assume that rest energy is localized due to measuring inertial effects. Since the hypothetical rest energy of a capacitor is a field that extends to infinity, we attribute the location of that energy as integrated over the universe.

When we measure the mechanical *inertial behavior* of "rest energy" (or energy in general) we measure what we call "mass" (that is, a time based measurement of opposition to a change in velocity). And it follows from the analog that when we measure the electrical *inertial behavior* of "rest energy" (or energy in general) we measure what we call "capacitance" (that is, time based measurement of opposition to a change in voltage). Since such properties are convertible in certain domains, one could argue they are different manifestations of the same property. In most interpretations of GR, we would expect any energy to affect spacetime (and without bias to the creation or existence of negative energy).

Length Contraction

A question that may arise from the analog regards Lorentz contraction. Although only indirectly

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observed in matter, it is considered valid, though interpretations differ and some seemingly inconsistent conclusions are still not satisfactorily resolved (typically variations of the Ehrenfest paradox).

We recognize that in the analog, the 1-d condition is satisfied by SR, and thus we expect length contract in the direction of motion. Voltage is an identical 1-d condition that is represented in terms of distance in the potential frame. This suggests that the distance between the objects at some electrical potential difference will contract when measured from either object that is not at the same potential as the frame – that is, the voltage cannot exceed *c* and therefore the space must contract to maintain $V=kQ/d$ in the potential rest frame of the relatively high potential object when measured from the non-copotential frame.

Obfuscation

The physical conjoining of fundamental units in isolated quantities conceals their identities across physical domains; this obscures the fact that they are indeed built from those same fundamental units and would most probably be subjected to similar physical constraints.

Comments on Inertia

The analogy suggests that inertia may be the consequence of field interactions in the manner capacitance responds to an applied current. Whereas mass resists a change in velocity, capacitance resists a change in voltage – each resists an increase in their energy content given the stimulus responsible for increasing such energy. The question is if this opposition to a change in energy has a fundamentally identical cause in each domain – that is, is inertia a counter force due to an induced field?

Experiments and Practical Applications

Possible Experiments

Anti-matter is formed in natural lightning discharges; current models cannot account for the required energy to produce the antimatter. It is possible that such energy is a result of relativistic capacitive charge increase, thereby allowing charge storage to attain higher energy levels than the electrical potential would suggest.

A possible test involves measuring the electrical potential in thunderstorms; so far these measurements are not conclusive; the potential should always measure less than 3×10^8 V; a literature search did not reveal any scientifically measured electrical potential reaching this value.

Lightning also exhibits peculiarities with regard to discharges that have not been adequately explained by avalanche phenomena. Reportedly, discharges can occur over much closer ranges than the electric potential and current models would suggest. It is possible that relativistic voltage effects, such as length contraction, are facilitating the phenomena.

A direct test can be performed using any suitable high voltage generation device; there are several options. Sufficient potentials have never been created in the laboratory; the highest man-made source found was from ORNL at 32 MV (http://www.ornl.gov/info/reporter/no3/labnotes.htm); but suitable

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devices can be built.

A tabletop (or small laboratory) experiment can be performed without needing the extreme voltages, but stable low-energy capacitors and inductors would be required at moderately high voltage levels and frequencies. By comparing resonant behavior over long periods at different voltages with a stable reference, predictable deviations from the classical behavior should accumulate (this can comprise a type of electrical interferometer or null device). As with any tests of relativistic behavior, the driving condition needs to be sufficient so that real effects are not swamped by deviations in the apparatus.

I plan to perform such tests as time and resources permit.

Practical Applications

If my hypothesis is not falsified, massive energy storage devices, spacetime manipulation machines, impulse engines, so-called "warp" drives, and all manners of science-fiction style technologies may come within our grasp – that is, if the physics can be applied. That said, it is too early to speculate on the practical details until the fundamental experiments have been performed.

Historical Information

Ampere: Formal Definition and Comments

BIPM: SI brochure (8th ed.), Section 2.1.1.4 Unit of electric current (ampere)
http://www.bipm.org/en/si/si_brochure/chapter2/2-1/ampere.html

NIST: http://physics.nist.gov/cuu/Units/current.html

"The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length."

This definition is proposed to be changed; my analysis is perhaps one reason *not* to change it; current is properly defined as a *force*. The proposed change is planned to be an elementary charge based definition; such an alternative definition may obfuscate certain natures of current, though it is reasonably valid in itself.

Heaviside and Gravitomagnetic Fields

A formal approach to an analogical model between electrodynamics and gravity was presented by Oliver Heaviside in 1893, in *The Electrician* prior to SR:

"A GRAVITATIONAL AND ELECTROMAGNETIC ANALOGY"

Part I, The Electrician 31, p. 281-282, 1893; Part II, The Electrician 31, p. 359, 1893

With this, Heaviside did not have the benefit of subsequent studies in the 20^{th} century, but the gravitomagnetic possibility was postulated here. This as a testament to the predictive qualities of analogs; experiments have been done to measure one modern interpretation and effect of this field (that is, frame-dragging). "Gravity Probe B: Final Results of a Space Experiment to Test General Relativity". Physical Review Letters 106 (22): 221101. suggests this effect may have been detected.

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