How Electrodynamics with Statistical Mechanics Can Imply Gravitation

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This paper shows how the phenomenon of gravitational attraction can arise from known Electrodynamics when it is combined with ideas from the discipline of Statistical Mechanics. The key input from Electrodynamics is the classical understanding about magnetic interactions between tiny current elements. The key input from Statistical Mechanics is the classical idea of distribution among possible energy states based on maximum entropy.

1. Introduction

The understanding of gravity that is currently considered the best available is Einstein's General Relativity Theory (GRT). It is considered to be an improvement over Newtonian Mechanics in that:

1) GRT is a tensor description, and so is manifestly invariant under change of coordinate reference frame;

2) GRT is believed to be more accurate in its numerical predictions than Newtonian Mechanics is;

3) GRT is believed to answer the question of 'how' that arises with Newtonian action-at-a-distance;

4) GRT is believed to fulfill four experimental tests (light bending by the Sun, planet perihelion advance for Mercury, Earth-space-Earth radar echo delay, GPS clock slowing).

But GRT also has some unfortunate deficiencies in comparison to Newtonian Mechanics. Unwinding the above list:

4) GRT is *not* known to fulfill *more* than those four experimental tests;

3) GRT answers the 'how' question in a *non*-physical, purely mathematical, way: the metric tensor - something every bit as mysterious as the aether of pre-Einsteinian physics;

2) GRT is *less* powerful than Newtonian Mechanics: it provides a mathematical solution in closed form only for the 'one-body problem' (one test particle in pre-established and non-adapting field), whereas Newtonian Mechanics can handle the 'two-body problem' (two particles interacting and influencing each other);

1) GRT is founded on Einstein's Special Relativity Theory (SRT), and, like many NPA members, I have deep misgivings about SRT. Most fortunately for us, the formal requirements for tensor description and invariance under change of coordinate reference frame do not at all preclude other theories that are alternatives to SRT, and hence GRT; in fact, they encourage them!

All this being said, it seemed appropriate to me to investigate additional approaches to the problem of gravity. This paper is a short report on one such approach.

2. Background

My personal hero in science predates Einstein; my hero is Maxwell. His coupled field equations lead to many interesting results, many of which are still to be appreciated fully and widely, even in the 21st century. For example, I have written before in NPA Proceedings [1] that for E and B field pulse inputs, Maxwell's coupled field equations behave in a manner inconsistent with Einstein's conception of a 'signal', which is the foundation for SRT. Given pulse inputs, un-coupled second order wave equations propagate the pulses without shape evolution, but first-order coupled field equations cannot propagate them without shape evolution. So the whole idea of 'signal speed' becomes complicated. It's a complicated scenario, not a simple speed.

My long-time friend Tom Phipps [2] has long been telling me that Maxwell's equations need extension, to put the velocity of the receiver in role of importance comparable to that of the velocity of the source. I agree on that objective, but prefer to address it differently, not within the differential equations themselves, but rather within the boundary conditions applied to build a particular solution. {3] I like to envision one boundary attached to the source, to prevent back-flow of energy, and another boundary attached to the receiver, to prevent overshoot of energy. Both boundaries can move arbitrarily. A subtler alternative to SRT then emerges, free of the famous paradoxes, and some infamous ones too, which were never even called out in the mainstream literature.

My GED colleague Jaroslav Klyushin [4] has long been telling me that gravity is a manifestation of Electrodynamics. He offers extended equations that involve, not only Coulomb scalar potential and Ampere vector potential, but also a 'gravidynamic' potential. Again, I agree with the objective in [4], but I see another way to serve it, to be developed below.

My long-ago MIT Professor Martin Schetzen recently published in GED his development of gravitational fields as analogs of the fields in Electrodynamics, especially with relative motion between the source of the gravitational signal and the receiver of that signal. [5] This relative-motion is of paramount importance for understanding why galaxies look the way they do, I believe. GRT hasn't had to face up to relative motion because it has dealt mainly with a pre-established, fixed-source gravitational field and non-disruptive tiny test particles moving in that field. Again, I agree with the objective in [5], but I see another way to serve it, to be further developed below.

The main ingredients I need in the following development come from Electrodynamics in the form that was known even *before* Maxwell, and from modern Statistical Mechanics.

3. Ampère Current Elements & Forces

Looking deep into history, before Maxwell, Ampère had a well-developed theory about forces between what he called 'current elements'. This term referred to charge-neutral material increments in electrical circuits.

Ampère's theory works perfectly well for ordinary closed circuits, and also for incomplete broken circuits, such as may exist momentarily in transient situations like explosions. Ampère's theory ought not be forgotten solely on the basis that more modern theory also works perfectly well for ordinary closed electrical circuits. Indeed, in some technological applications involving rupture of circuits, Ampère's theory explains more than the modern theory does. [6]

Ampère's force formula can be written:

$$\Delta F_{m,n} = +i_m i_n \left[\Delta m \ \Delta n / (r_{m,n})^2 \right] \left(3\cos\alpha\cos\beta - 2\cos\gamma \right) \quad . \qquad (1)$$

The indices m and n identify two interacting currents. The i_m and i_n are current magnitudes. The Δm and Δn are magnitudes of tiny directed length increments $\Delta\mathbf{m}$ and $\Delta\mathbf{n}$ through which the currents flow. The products of currents and directed length increments, $i_m \Delta\mathbf{m}$ and $i_n \Delta\mathbf{m}$, are the current elements. The $r_{m,n}$ is the length of the vector separation $\mathbf{r}_{m,n}$ between the current elements. The α, β, and γ are angles with respect to the connecting line between the two current elements, and with respect to each other. Current element $i_m \Delta\mathbf{m}$ is at angle α from the connecting line, and current element $i_n \Delta\mathbf{n}$ is at angle β from the connecting line. The γ is the angle between the two planes defined by the connecting line and each of the two current elements, as if the distance $r_{m,n}$ did not separate them. The value ranges are all full circle:

$$0 < \alpha < 2\pi \quad , \quad 0 < \beta < 2\pi \quad , \quad 0 < \gamma < 2\pi \quad . \qquad (2)$$

One can get a feel for the general behavior of Ampère's force formula by considering the angle factor $3\cos\alpha\cos\beta - 2\cos\gamma$ for a few special cases:

1) Current elements side-by-side and parallel, as in parallel wires. Both current elements are perpendicular to the connecting line, so α and β are $\pi/2$ and $\cos\alpha$ and $\cos\beta$ are zero. But γ is zero, and $\cos\gamma = 1$, so the angle factor evaluates to -2. The force $\Delta F_{m,n}$ is then negative. The current elements attract each other. If they reside in parallel wires, the wires attract each other. This you know from experience is true. In a plasma, instead of solid wires, it is called the 'pinch effect'.

2) Current elements side-by-side, but anti-parallel. This is just the opposite to Case 1 above: now $\gamma = \pi$ and $\cos\gamma = -1$. The current elements repel each other. If they reside in a circuit, that circuit likes to straighten out any kinks and enclose more area. This you may know from experience is true.

3) Current elements end-to-end, as in an electrical circuit. All three angles are zero, all three cosines are unity, and the angle factor evaluates to $+1$, so the force $\Delta F_{m,n}$ is positive. The current elements repel each other. You may *not* know from personal experience that, if the current gets too large, the wire may actually rupture longitudinally!

4. Ampère's Force Law and Gravity

The $1/(r_{m,n})^2$ aspect of the Ampèr force law is just like Neton's law for gravity. In fact, Ampère designed his law that way, because at his time the greatest prior achievement in science was Newton's conquest of gravity.

Now we wish to return the favor, and exploit the Ampère Force Law to understand something new about gravity. So what new can Ampère's force law suggest about gravity? Instead of neutral current elements, please think about neutral atoms. At any moment in time, any atom is *very* like an Ampère current element: it is charge neutral, and its electrons are moving, and while its nucleus is moving too, it is moving not anywhere near so much, so there is a net current flowing.

Add to this idea a rather hierarchical vision of atoms in general [7], in which the electrons are a rather self-contained subsystem that has internal interactions, but overall orbits the nucleus a lot like the single electron orbits the proton in the prototypical Hydrogen atom. That will make for an Ampère force between any two atoms. The force may be steady, or may vary in time, and may well vary in sign. This situation is very complex, but very rich in promise.

The concept that current elements generate forces that can attract or repel each other suggest that pairs of current elements – or pairs of atoms - can be regarded as a system that can have positive or negative total energy. The kinetic part of the energy may be disregarded, since the current elements may be essentially static, but the potential energy is worth paying attention to. Observe that it will be proportional to $1/r_{m,n}$. Again, we have something quite like gravity.

The main difference that gravity presents is that we usually have not two atoms, but huge numbers of atoms. Each atom must have some relationship to all the other atoms. With atoms viewed as current elements, some relationships are attractive and some are repulsive, and all must vary over time.

6. A Role for Statistical Mechanics

Alternatively, one can look at the population of atom pairs as a whole, and think of it as a statistical ensemble, in which every condition of attraction/repulsion is represented somewhere. The complexity of the situation naturally conjures up the ideas of Statistical Mechanics.

Now the central concept in Statistical Mechanics is that lower-energy states are populated more than higher-energy states are. This concept means that any two atoms, viewed as current elements, will be in a state of negative potential energy more often than in a state of positive potential energy with respect to each other. So they will, on average, attract each other more than repel each other.

We can even begin to quantify this idea. Consider some possible states of two atoms viewed as current elements. They could be stacked, with the electron orbits in parallel planes. The electrons could be circulating in the same direction and in phase, one always above the other. That would be an attractive-force condition, a negative potential-energy condition. Or the electrons could be circulating in the same direction but out of phase, always moving in opposite directions. That would be a repulsive-force condition, a positive potential-energy condition.

It has to be acknowledged that it might not be the exact same magnitude of potential energy in both cases. Why? Because the electron orbit has a finite radius, and that means the effective distance between counter-moving electrons can be microscopically more than that between commoving directions. But for the moment we can neglect this detail, and say that, to first order, the two potential energies differ only in sign: $-E$ and $+E$.

I will leave E as a symbol, representing the function of currents, i_m, i_n, length increments, $\Delta m, \Delta n$, and angles α, β, γ, that appears in the Ampère's force formula, divided by the separation magnitude, $r_{m,n}$ (rather than the separation squared, $(r_{m,n})^2$, for force).

Statistical Mechanics says the two energy states $-E$ and $+E$ will be populated in proportion to their so-called 'Boltzmann factors'. A Boltzmann factor is an exponential with argument of minus state energy divided by population average energy. In classical Statistical Mechanics, population average energy is expressed as Boltzmann constant k times temperature T. In the present application, temperature has no relevance. So the population average energy is just represented by the symbol $<E>$, meaning statistical average value.

With the attractive–force, negative-energy state dominating, $<E>$ must be negative. With $<E>$ being *negative*, the two Boltzmann factors have to be:

$$\exp(-E/<E>) \text{ for the state with negative energy } -E \quad ,$$

$$\exp(+E/<E>) \text{ for the state with positive energy } +E \quad .$$

The population average energy is then defined implicitly by the relationship

$$<E> = \frac{-E\exp(-E/<E>) + E\exp(+E/<E>)}{\exp(-E/<E>) + \exp(+E/<E>)} \quad . \tag{3}$$

This expression for $<E>$ can be re-written

$$\begin{aligned} <E> &= (-E)\frac{\sinh(-E/<E>)}{\cosh(E/<E>)} = E\frac{\sinh(E/<E>)}{\cosh(E/<E>)} \\ &\equiv E\tanh(E/<E>) \quad . \end{aligned} \tag{4}$$

The simplified equation $<E> = E\tanh(E/<E>)$ can be solved with a hand calculator. Just put

$$x = E/<E> \quad \text{and} \quad 1/x = \tanh(x) \quad . \tag{5}$$

and try some x values. The appropriately negative solution is about $x = -1.2$, or $<E> = -E/1.2 = -\frac{5}{6}E$. So, for a pair of positive and negative potential energy states of equal-magnitude E, the populations will favor the negative-energy state over the positive-energy state to the extent that the average energy will be about $-\frac{5}{6}E$.

6. Injecting More Realism

Of course the analysis above is vastly simplified, with its limitation to a single value of E, and hence just two states, with energies $-E$ and $+E$. The real problem has a variety of E values because of a variety of angle values, α, β, and γ. The next level of realism would allow a discrete set of angle possibilities, distinguished by an index k:

$$\begin{aligned} <E> &= \frac{\sum_k -E_k\exp(-E_k/<E>) + E_k\exp(+E_k/<E>)}{\sum_k \exp(-E_k/<E>) + \exp(+E_k/<E>)} \\ &= \sum_k E_k\sinh(E_k/<E>) \Big/ \sum_k \cosh(E_k/<E>) \end{aligned} \quad . \tag{6}$$

Given a reasonably small set of E_k values, this expression is simple enough for an EXCEL calculation on a PC. Note that generally, every amplitude of every angle cosine recurs four times, so every value of angle factor $3\cos\alpha\cos\beta - 2\cos\gamma$ recurs $4^3 = 64$ times. So only $1/64$ of all possible cases actually have to be considered in a computer code for generating the E_k.

Note that with more states included, the $<E>$ more reflects the E_k's in the middle of the population, which have smaller magnitudes E_k because of the angle factor $3\cos\alpha\cos\beta - 2\cos\gamma$. That makes $<E>$ smaller. In addition, the samplings of α, β, and γ all need to be weighted for uniformity, with factors of $\sin\alpha$, $\sin\beta$, $\sin\gamma$. This further emphasized the middle of the population, with its smaller magnitudes of E_k.

For even more realism, one could allow a continuum of angles:

$$<E> = \frac{\int_{\alpha,\beta,\gamma} E(\alpha,\beta,\gamma)\sinh\left[E(\alpha,\beta,\gamma)/<E>\right]}{\int_{\alpha,\beta,\gamma} \cosh\left[E(\alpha,\beta,\gamma)/<E>\right]} \quad . \tag{7}$$

But this formulation may be more of a conceptual description of the problem than the basis for a practical solution approach!

The denominators in the successively more complete formulae for $<E>$,

$$\cosh(E/<E>) \quad ,$$

$$\sum_k \cosh(E_k / <E>) \quad ,$$

and
$$\int_{\alpha,\beta,\gamma} \cosh\left[E(\alpha,\beta,\gamma)/ <E>\right] \quad ,$$

are successively more complete expressions of what in Statistical Mechanics is always called the 'Partition Function', and often represented as the letter Z. You can see that generally:

$$<E> = \frac{1}{Z}\frac{\partial Z}{\partial(1/<E>)} = \frac{\partial \log(Z)}{\partial(1/<E>)} \quad . \tag{8}$$

This way of looking at the Ampère Energy problem recalls formulae from various other problems familiar in Statistical Mechanics and Thermodynamics. There, the basic idea is that everything there is to know about a thermodynamic system is embodied in its Partition Function, and the master variable that in turn determines the partition function is the temperature T. Here, the basic idea is similar, but there is no externally supplied master variable T; there is just an implicit relationship for $<E>$, and so far as I can see, it has to be solved computationally.

7. From Statistical Mechanics to Gravity

So far, this analysis discussed just one pair of atoms with just two orientations, one attractive (negative E) and one repulsive (positive E). Any pair of atoms actually has infinitely many possible pairs of orientations, with infinitely many different numerical values of E. And within any macroscopic body, there will be many interacting pairs of atoms at different separations, expanding further the range of numerical values of E. And then between any two macroscopic bodies, there will be many more separation values, and more E values.

The statistical argument still always applies: negative E will always be statistically more common than positive E. The statistical argument based on Boltzmann factors creates a bias toward Ampère attraction over Ampère repulsion. This statistically based prediction is the basis for a candidate explanation for the phenomenon of gravitational attraction.

Can this candidate explanation make sense numerically? What we know of the gravitational force is that it is extremely weak compared to Coulomb attraction/repulsion. So it doesn't take much of a bias based on Electrodynamics to do the job.

Let us compare the maximum Ampère force with the gravitation force between two hydrogen atoms at a given separation distance $r_{m,n}$.

The maximum Ampère force is proportional to

$$e^2 (v/c)^2 \quad ,$$

where e is the charge of the electron, about 1.6×10^{-19} Coulomb, so e^2 is about 2.56×10^{-38} Coulomb^2, or Newton $\times$ meter^2, and where v/c is the ratio of the electron orbit speed to the speed of light, which in the ground-state hydrogen atom is about 0.67×10^{-2}, so that $(v/c)^2$ is about 0.5×10^{-4}. Overall,

$$e^2 (v/c)^2 \approx 1.3\times 10^{-42} \text{ Newton} \times \text{meter}^2 \quad . \tag{9}$$

The gravitational attraction is proportional to

$$G(m_\mathrm{p})^2 \quad ,$$

where G is the universal gravitation constant, about 6.6×10^{-11} Newton $\times$ meter^2 per kilogram^2, and m_p is the mass of the proton, about 1.66×10^{-27} kg, so $(m_\mathrm{p})^2$ is about 2.76×10^{-54}. Overall,

$$G(m_\mathrm{p})^2 \approx 1.8\times 10^{-64} \text{ Newton} \times \text{meter}^2 \quad . \tag{10}$$

Clearly, the maximum Ampère force is generously larger than the gravitational force. The average Ampère force will be smaller because of the angle factors – their magnitude and their relative occurrence. How *much* smaller presently remains to be worked out. But the average Ampère force definitely cannot be zero, and so it cannot presently be excluded as a candidate explanation for gravitational attraction.

8. Can We Understand Anti-Gravity?

The stated relationship (5),

$$1/x = \tanh(x) \text{ with } x = E/<E> \quad , \tag{11}$$

does also possess a positive-energy solution of the same magnitude as the negative-energy one:

$$<E> = +E/1.2 = +\tfrac{5}{6}E \quad . \tag{12}$$

This second solution represents a state similar to the state of a population of atoms that leads to laser action. This kind of state is called 'inverted', meaning that the higher-energy states of the atoms are more populated than they normally would be. The inverted population state obviously exists in the laser case, but it takes some clever technology to get into that state. In the present context, the enabling technology would merit the name 'anti-gravity'. We don't presently know exactly how to produce the anti-gravity inverted state, but based on the laser precedent, we have every reason to believe that it can be done.

Obviously, exploitation of electromagnetic phenomena should be important for doing this engineering job. We have seen that suggestion various times in GED. For example, Ridgely [8] attributed claims of induced variable weight to some electromagnetic effect generally, Spears [9] related G to electrostatics in particular, and Adewole [10] made a unified theory of gravity and electromagnetism under the assumption that electromagnetic fields induce gravitational ones, and *vice versa*.

Humans have not convincingly done the anti-gravity engineering job yet, but Nature may well have done it already. One of the enduring mysteries we have all wondered about is the apparent rarity of antimatter in our known world. We are totally dominated by normal matter. For example, we see mainly electrons, and only occasionally the transient anti-electron, the positron. What does this asymmetry mean? Is there some distant corner of the Universe where the situation is reversed? Does that in turn mean that islands of matter and islands of antimatter repel each other? Is it correct to call such a phenomenon 'anti-gravity'?

If gravity is indeed a statistical residue of Ampère forces, that kind of gravitational repulsion could indeed exist. The statistical distribution of angles that makes normal matter attract normal matter would also make antimatter attract antimatter, but it would then make the cross combination, normal matter with antimatter, generate mutual repulsion.

9. Dark Matter and Dark Energy?

Out there in the Universe, processes occur that we do not understand. The tendency is to postulate exciting new physics for them. So it is with 'dark matter' and 'dark energy'. We don't understand why galaxy rotation is not Keplerian in its profile of orbit speed *vs*. radial position, so we postulate dark matter. And we don't understand why distant galaxies recede from us, so we postulate dark energy. But maybe things are really more pedestrian than all that.

If gravity is really electromagnetic in character, then there is good reason to believe, as Einstein apparently *did* believe, that its description should involve light speed c . Does this mean gravity is a signal that travels? Or can gravity nevertheless be instantaneous, as it was for Newton? Which way did Einstein see it? Both ways, I think. The idea of using the metric tensor and the spacetime curvature may allow the instantaneous view, but then the idea of gravitational waves may allow the travel view.

I am inclined to believe only in the signal that travels, in a manner not unlike a light signal. This gravitational signal takes finite time to propagate. This is important. Signal propagation delay causes some well-known phenomena in engineering systems. Things can get out of hand – go unstable. And that situation cannot be very different in stellar systems.

In the case of a single galaxy, suppose there is a massive two-body system at the center, say two black holes. The gravitational signals from that central system take time to arrive to the millions of much smaller stars that make the rest of the galaxy. The delay means the signal that finally arrives to a distant star points to where the signal source was a long time ago, not where it is now. Forces are not central. The result is a torque on the system overall, causing all stars to move outward, making the outermost reaches of the galaxy more and more full of older, darker stars, and affecting the whole speed profile. 'Dark Matter', is, I think, really just the name given to old, dead stars that have migrated outward because of the propagation delay of the gravitational signals that bind them.

On a larger scale, propagation delay of gravitational signals can cause whole galaxies to wander away from each other, and thus cause galaxies to recede, and the whole visible Universe to expand. 'Dark Energy', is, I think, really just the name given to a manifestation of the finite propagation speed of gravity. Expansion occurs, I think, because gravitational signals are really electromagnetic signals.

There exists plenty of dramatic visual evidence that can be interpreted in terms of propagation delay of gravitational signals. The ubiquity of barred spiral galaxies everywhere we look invites just such an explanation. [11,12]

10. Conclusion

This short paper marks the beginning of a probably long investigation. One pressing objective is to use the concept of neutral atoms interacting as neutral current elements do, via Ampère forces, along with the relevant concepts from Statistical Mechanics, to arrive finally at a theoretically based numerical value that approximately matches the empirically determined numerical value of Newton's gravitational constant G .

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