Lessons from the Field
The 2013 John Chappell Memorial Lecture

Cynthia Kolb Whitney
Editor, Galilean Electrodynamics
141 Rhinecliff Street, Arlington, MA 02476-7331
e-mail Galilean_Electrodynamics@comcast.net

Like most of you listening to this lecture, or reading this hardcopy later, I have been on a life-long journey, meandering to be sure, but progressing I think. I believe in the possibility of reaching a place where there will be a bit more understanding about what is going on in the physical universe. Along the way, I have gotten swatted down a lot. So will you. But there are some funny stories to tell about all those swat experiences, and laughter does overcome just about everything. So herein are my best 'Swat Stories'. I hope my stories will help you through your own journeys.

1. Introduction

First, let me speak of meandering. I was an MIT student in the late 50's and early to mid 60's. In those days, MIT required a thesis for every degree, including the science bachelor's degree, SB. My Physics SB thesis supervisor was Walter Thorson, in the Chemistry Department. He was doing the sorts of things that are today characterized as 'Quantum Chemistry'. I learned that the simplest molecule imaginable, the Hydrogen molecule, was really very complicated. It required 'two-center exchange integrals', integrals of big functions written in ellipsoidal coordinates. The work took a big computer, eating big boxes of punched paper cards, and producing big piles of folded-up paper output. I learned that I did not want to study this subject in this way any more. But I *did* want to study it more in some *other* way - later.

I investigated graduate schools, and was interviewed for a Woodrow Wilson fellowship at Harvard. But, maybe honest to a fault, I confessed that I really wanted to continue at MIT. So that is what happened. My husband Dan and I started MIT graduate school together in 1963. He gave me great advice: pause on the way to the Physics PhD, and get an Electrical Engineering SM. It would make me employable no matter what!

EE had really interesting people. There was Parry Moon, and, by association, Domina Eberle Spencer. It was decades before I fully appreciated what wonderfully radical people they were. Parry taught me Field Theory in cruel and unusual circumstances (reminiscent of that Hydrogen Molecule), and he taught me tensor algebra too. I learned to just be patient, read the tensor indices, and do what they specified to do. Decades later, that calming message would help me in regard to Maxwell's equations and Galilean invariance. Everyone had always believed there was a big problem there. But I realized that the problem could be solved, if we would just use two more tensor index positions to specify two more kinds of transformation, besides the familiar covariant and contravariant. [1]

Also in EE was the intellectual dynasty of Norbert Wiener, Y.W. Lee, and Martin Schetzen. They made me love statistical methods so much that I even took the statistical courses in the Physics Department. The ideas from those courses have been the key to the gravity paper of mine that also appears in this book.

Back on the Physics track, I stumbled into the office of Prof. Laszlo Tisza. He set me onto Special Relativity Theory (SRT). The job at hand was to express the theory more beautifully by using 2X2 complex Pauli matrices. Too young and ignorant to realize just how august Prof. Tisza really was, I did not hesitate to argue with him about the matrices. He loved that! And one time, I actually was not wrong! That was a pretty good first 'Lesson from the Field': always go ahead and argue.

Years later, Prof. Tisza revealed to me some quiet conversations among the physics faculty that he had overheard at a departmental tea years before that. The physics professors were talking about, not the mathematical formalism, but rather the actual substance, of SRT. They had private doubts. Somebody colorfully remarked that it was going to take decades to correct all of Einstein's mistakes!

By that time, I was working at Charles Stark Draper Laboratory, once a part of MIT, but later an independent institution. I was working among engineers who sent people to the Moon, and other such tasks. (I told you that the engineering degree would be valuable.) The engineers did *not* believe in SRT. Some of them, including myself, were dealing with ring laser gyroscopes, which are based on the Sagnac effect. For SRT, the Sagnac effect is a very inconvenient physical truth. But I argued with those engineers for quite a while. In fact, I argued for a whole decade. And I lost.

2. Epiphany

The thing is, engineering often amounts to system-control engineering. An engineering system works by taking measurements from sensors of some kind, calculating the implications of the data, and then sending commands to actuators of some kind. Timing matters. If there is some cyclic process going on, and the time needed for sensing, computing, and commanding is too long, then the system can go unstable, and spiral out of control. This was on my mind one day when my husband and I took our sons David and Karl to the Boston Museum of Science. One exhibit we saw was a flat table with a spin-able disc containing a pearly-looking liquid. Upon spinning, the device created spirals that looked eerily like the arms of a spiral galaxy.

It hit me like a 2X4 over the head that the liquid might look like spirals because the information about the disc being spun propagated through the fluid at a finite speed. I speculated that spiral galaxies might look the same way for a similar reason; namely, that gravitational signals travel at a finite speed, and so arrive with a propagation delay. The boys and I scampered up the stairs to the museum library to see what authorities said about the consistency of spiral galaxies.

Of course there was no past literature about an idea like mine. And I soon found there was no current audience for it either. All the appropriate journals swatted it away without comment.

Several MIT professors directed me to the subject of electrodynamics to see the reason why. Back at the turn of the 20th century, a number of researchers had addressed the problem of modeling the potentials and fields created by a rapidly moving source. They had all taken, without even remarking on it, the same seemingly obvious assumption that Einstein later formalized as his Second Postulate: The speed of light has the same value c for all observers in all inertial reference frames. (Einstein deserves much credit for even noticing that there was an assumption there, waiting to be stated explicitly.)

3. Consequences of the Hidden Assumption

Given the assumption, the results are inevitable: they are the Lienard-Wiechert scalar and vector potentials for electric and magnetic fields. Expressed in Gaussian units (Jackson [2]), the Liènard-Wiechert potentials expressed in Gaussian units are:

$$\Phi(\mathbf{x},t) = e\left[1/\kappa R\right]_{\text{retarded}} \quad \text{and} \quad \mathbf{A}(\mathbf{x},t) = e\left[\vec{\beta}/\kappa R\right]_{\text{retarded}}, \quad \text{(1a,b)}$$

where $\kappa = 1 - \mathbf{n}\cdot\vec{\beta}$, $\vec{\beta}$ is source velocity normalized by c, and $\mathbf{n} = \mathbf{R}/R$ (a unit vector), and $\mathbf{R} = \mathbf{r}_{\text{observer}}(t) - \mathbf{r}_{\text{source}}(t - R/c)$ (an implicit definition for the terminology 'retarded').

The Liènard-Wiechert fields expressed in Gaussian units are then:

$$\begin{aligned}\mathbf{E}(\mathbf{x},t) &= -\nabla\Phi(\mathbf{x},t) - \frac{1}{c}\frac{\partial}{\partial}\mathbf{A}(\mathbf{x},t)\\ &= e\left[\frac{(\mathbf{n}-\vec{\beta})(1-\beta^2)}{\kappa^3 R^2} + \frac{\mathbf{n}}{c\kappa^3 R}\times\left((\mathbf{n}-\vec{\beta})\times\frac{d\vec{\beta}}{dt}\right)\right]_{\text{retarded}}\end{aligned}$$

and $$\mathbf{B}(\mathbf{x},t) = \nabla\times\mathbf{A} = \mathbf{n}_{\text{retarded}}\times\mathbf{E}(\mathbf{x},t) \quad .$$

The Liènard-Wiechert fields have some interesting properties. The $1/R$ fields are radiation fields, and they make a Poynting vector that lies along $\mathbf{n}_{\text{retarded}}$:

$$\begin{aligned}\mathbf{P} &= \mathbf{E}_{\text{radiative}}\times\mathbf{B}_{\text{radiative}}\\ &= \mathbf{E}_{\text{radiative}}\times\left(\mathbf{n}_{\text{retarded}}\times\mathbf{E}_{\text{radiative}}\right)\\ &= E^2_{\text{radiative}}\mathbf{n}_{\text{retarded}}\end{aligned}$$

But the $1/R^2$ fields are Coulomb-Ampère fields, and the Coulomb field does *not* lie along $\mathbf{n}_{\text{retarded}}$ as one might naively expect; instead, it lies along $(\mathbf{n}-\vec{\beta})_{\text{retarded}}$.

Consider the following scenario from [3], designed specifically for an instructive exercise in *reductio ad absurdum*. A source executes a motion comprising two components: **1)** inertial motion at constant $\vec{\beta}$, plus **2)** oscillatory motion at small amplitude and high frequency, so that there exists a small velocity $\Delta\vec{\beta}_{\text{retarded}}$ and a not-so-small acceleration $d\Delta\vec{\beta}/dt\big|_{\text{retarded}}$. The absurdity is that the radiation and the Coulomb attraction/repulsion *come from different directions*. The radiation comes along $\mathbf{n}_{\text{retarded}}$ from the retarded source position, but the Coulomb attraction/repulsion lies along $(\mathbf{n}-\vec{\beta})_{\text{retarded}}$, which is basically $(\mathbf{n}_{\text{retarded}})_{\text{projected}}$, and lies nearly along $\mathbf{n}_{\text{present}}$.

Taking the Coulomb attraction/repulsion as an analog for gravitational attraction, one has to suppose that gravity forces are nearly central, as if instantaneous, just as Newton first imagined them to be. They could not then produce those spiral patterns in the galaxies. Therefore, the subject of my investigations had to switch from Gravity to Electrodynamics!

4. A More Useful 'Swat Story'

All standard textbooks, using whatever derivation method they may choose, arrive at the Liènard-Wiechert field expressions. But to me, the Liènard-Wiechert field behavior seemed peculiar. How could it be that observations of an arbitrarily moving charge would consist of radiation coming from one direction, and attraction/repulsion coming from another direction?

I wrote to Jackson about this issue. In fact, I wrote several times. Indeed, I was a pest. His final words back to me in 1988 were in part: "…You are being disingenuous, if not deliberately dishonest. … the business is a triviality. … Do not waste my time or your own on such nonsense. …"

That attempted swat-down just inspired me anew! Jackson was surely right that, if you believe Einstein in all particulars, then you *do* have to believe in the behavior predicted by Liènard-Wiechert field expressions. But I was not personally able to believe in that predicted behavior. So I was not able to believe Einstein in all particulars. His, and everybody else's, math was OK, and if the results were screwy, then it was everybody else's hidden assumption, and his explicit Second Postulate, that had to be wrong!

5. A Path Forward

Around that time NPA was coming into existence. Personalities like Domina Eberle Spencer, with encouragement from her husband Parry Moon, and John Chappell, Francisco Muller, Peter Graneau, and so many others, were creating a nurturing environment for us all. Domina knew everything about postulates, and everything about 19th century mathematicians too. I have gradually come to appreciate what applied mathematicians of that day might have done different from what Einstein actually did. Those applied mathematicians would have dealt in differential equations, a family of solution functions, boundary conditions to describe the particular problem at hand, and construction of a combination of solution functions to fit the boundary conditions. Einstein didn't do any of that for SRT. He just made his one-sentence Second Postulate about light speed being a universal constant; call it c.

Einstein did not really like Mathematics at this early time in his life; his appreciation for Mathematics came only later, when colleague mathematicians used tensors to explicate the mysteries of his General Relativity Theory (GRT). (It is of course an irony that, while SRT cut through the muck and banished the undetectable 'luminiferous aether' filling space, GRT essentially brought it back, but under an alias, as the 'metric tensor' filling space.)

I wrote a fuller story about the math missing from SRT last year, in [4]. The differential equations are Maxwell's four first-order coupled field equations. The family of solutions consists of generating Gaussians and the Hermite polynomials that the Gaussians generate with the differential operators in Maxwell's equations. The family of solutions consists of Gaussian field pulses with finite energy that develop into Hermite-polynomial field wavelets. The boundary conditions are: 1) no backflow of energy to behind the source, and 2) no overflow of energy beyond the receiver. The boundary conditions are enforced by zero E field at the source and at the receiver. The particular solution sought is a combination of different Gaussian field pulses with finite energy at different phantom moving origins, developing into different Hermite polynomial field wavelets coming from the different phantom moving origins, such that the stated boundary conditions, zero-E at source and receiver, are always met. The total solution, complete with contributions to fulfill boundary conditions, has an energy profile that starts half a wavelength wide at the source, but spreads out as it travels, and then piles up as it arrives at the receiver. It is smooth, but changing in longitudinal shape over time. (This is the proverbial 'Arrow of Time' at work.)

The ever-changing shape of this signal model makes it tricky to assign a single speed to it. Here is one way to approach the job: At every moment, the signal energy profile has a 'median' point – with half the energy before, and half the energy after. Because of the boundary conditions imposed, this median point certainly starts from the source at speed c relative to the source, and it certainly arrives to the receiver at speed c relative to the receiver. In between, a complicated transition gradually occurs.

Maybe this signal model sounds too complicated, but it is realistic, and it prevents the various paradoxes that plague SRT. Most particularly, it resolves the problem with the Liènard-Wiechert formulation of the fields. Now the decisive direction in the problem is the direction from source to receiver at the temporal mid point of the scenario. The Coulomb attraction/repulsion lies along $(\mathbf{n}-\vec{\beta})_{\text{half retarded}}$. Note that $(\mathbf{n}-\vec{\beta})_{\text{retarded}}$ is essentially $\mathbf{n}_{\text{present}}$, so $(\mathbf{n}-\vec{\beta})_{\text{half retarded}}$ is $(\mathbf{n}_{\text{present}})_{\text{half retarded}}$, or simply $\mathbf{n}_{\text{half retarded}}$. And the radiation comes along $\mathbf{n}_{\text{half retarded}}$ too, so the two previously different arrival directions are now reconciled to one arrival direction.

6. A Few Speculations

History is tough enough when we try to piece together surviving documents to diagnose what events actually transpired at a far removed time. But when we are curious as to why some obviously appropriate thing did *not* happen, then history is even tougher. That is the situation here.

We know that the Michelson-Morley experiment had been a thorn in everybody's side, and it demanded some sort of a 'master stroke'. We don't know if that was, or was not, the situation that enlisted Einstein, but enlisted he was, to become the master.

I think I understand why Einstein did not initially explore in the direction outlined here: he had been thinking about riding infinite plane waves of light since adolescence. He *a priori* concept for light was the infinite plane wave. It was natural for him to use that concept to formulate his Second Postulate.

But Einstein worked on SRT and on the photoelectric effect at almost the same time. Why did he not then 'connect the dots', as we say today, and see a similarity between the 'photon' in the lab and the 'signal' in SRT? Was the photon just too new?

One key difference between the infinite plane wave and the photon is infinite energy *vs*. finite energy. The photon has definite, finite energy. Modern 20th century Information Theory tells us that an infinite plane wave cannot convey information. That is because there is no discernable 'before-and-after' to it – it just continues forever. It has none of what is called 'negative entropy', or 'neg-entropy', or 'information'.

Only a finite-energy entity can convey information. Transmission of information generally relies on pulses of some sort. The photon has the capability to function as a signal. The infinite plane wave does not have that capability.

But in the early 20th century, the concepts of Information Theory had yet to be invented. Einstein knew something about entropy from Thermodynamics, and he could have invented Information Theory right then and there. But he didn't.

Concerning his signal, Einstein said practically nothing other than the equivalent of 'c'. Did he imagine a pulse of energy that would propagate, but not change in shape? Such a permanent-shape pulse can satisfy the second-order uncoupled wave equations that can be obtained by inserting Maxwell's first-order coupled vector field equations into each other. But it cannot satisfy Maxwell's first-order coupled-field equations themselves. So it is a rather tenuous way to represent Maxwell within SRT.

Did Einstein imagine a more adequate signal model, such as the one described here? If he had imagined such a detailed model, then he would have said more about it than just 'c'.

And what about all the applied mathematicians of the day? They became engaged later with GRT, but seem not to have revisited SRT in the way it deserved.

Maybe we should rely on Nature itself, rather than any such personalities. One thing we know for sure exists in Nature is the photon. One thing we know for sure does *not* exist in Nature is the infinite plane wave. So which of these two things makes the better model for the 'signal' needed in SRT? I favor the finite-energy one.

7. Finding an Interested Audience

The resolution of this particular problem in SRT can do a lot in other areas, all of which can marshal an audience. In [4], I talked about some implications in Quantum Mechanics (QM), concerning the stability and parameters of the Hydrogen atom, excited atomic states, bigger atoms, and molecules. In [5] I talked about Cold Fusion.

NPA publications can lead to other publications too. The open-access publisher Intech invited [6] and [7]. These long essays are focused on the main interest of this publisher, which is Quantum Mechanics.

Ref. [5] led directly to Ref. [8]. The main interest of this publisher is technology, especially for Cold Fusion, which has a lot of electrochemistry in it.

Ideas focused on Chemistry overall are collected in my full book [9], which is now available, both from Nova Science Publishers directly, and on Amazon.com.

There is an amusing 'Swat Story' about my book. It has three major sections, corresponding to practical applications, roots in QM, and deep roots in electrodynamics. When I first wrote the book proposal, I had the Sections in the opposite order: foundations in electrodynamics, developments in QM, and applications in Chemistry. The publisher was not interested. But some instinct told me what their reason was. My whole structure had been just too close to my own personal history: getting dissatisfied in SRT, applying something different in QM, and then getting a handle on a range of applications in Chemistry. So I reversed the order of presentation: practical observations and applications first, QM models second, and deep physics last, and writ quite small too. Then the publisher accepted the proposal right away! There is some important 'Lesson from the Field' there. I think it is more or less this: Always look at things from the viewpoint of your customer!

8. A List from my Book

My book concludes with a list of more detailed 'Lessons from the Field'. I want to summarize them here:

1) Putting practical applications first defers any upsetting information about faulty conventional wisdom to later consideration. In my experience, no other approach has worked anywhere near as well. So for presentation purposes, it can help to 'Reverse the Research'.

2) Let any upsetting bits embody the following script: "It is generally believed that (fill in the blank) occurs (or doesn't occur). But numerical analysis shows that the general belief is not very likely to be true, whereas an alternative scenario (fill in the blank) is really more likely." This script works well. So always remember: 'Nail the Numbers'.

3) My Chapter about the Hydrogen atom reflects a typical engineer's question: What is the minimum system we can talk about? The Hydrogen atom involves acceleration, so it has to have at *minimum* two charges. Early 20th century analyses focused on *one* charge. That approach left many troubling mysteries, such as exploding electrons and run-away solutions. So it is a good idea to 'Restrain the Reductionism'.

4) My Chapter about photons, like the short version here, noted the long-ignored quirkiness of the Liénard-Wiechert formulae, and then tracked it down, and then resolved it. You should always 'Question any Quirkiness' you may detect, and then chase it to some sort of resolution.

5) My Chapter about tensor analysis showed this new mathematical technique that was eagerly adopted for a new branch of Physics (*i,e*, SRT) being turned back to illuminate the shaky foundations of that new branch of Physics. So, when you learn to use a new math tool, always 'Review Earlier Research'.

6) The application of all such tools together, and any other ones you may think of, constitutes 'Due Diligence'. Whatever you do in life, you should always perform Due Diligence to the best of your ability.

9. Conclusion

As you can probably tell, I am interested not only in Physics itself, but also in the communication problems that clearly impede its progress. People who entertain novel ideas are often swatted down, and do not get to be heard. The NPA, and people like John Chappell, are to be thanked for giving us all a voice.

In addition, the many authors who have written papers for NPA Proceedings are to be thanked by those of us who edit them. Editing is great practice for communicating! Try editing someone else's paper, and you will surely discover something important about communicating better.

I would guess that many of you NPA listeners/readers have 'Swat Stories' to share. I am very interested in these things. Please tell me about them. Maybe from such discussions a path forward will emerge for you. Maybe the 'Lessons from the Field' will mean fewer 'Swat Stories' in your future.

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