When is a Field Theory not a Field Theory ?

Dr. Neal Graneau, D.Phil, F.InstP
ELiquiGen Ltd.
7 Coniston Ave., Oxford, OX3 0AN, UK
neal.graneau@googlemail.com

By default, any experimental result that cannot be explained by a field theory must be caused by objects interacting in the manner historically described as "Instantaneous Action At A Distance" (IAAAD). In more than two thousand years of research into the laws of physics from the time of Aristotle until today, no other matter interaction paradigms have been proposed. Until the emergence of Isaac Newton's pioneering exposition, "Principia", the earlier physical models have all envisaged that the space between objects was completely filled with aethers and swirling vortices. Matter was purported to both influence these undetectable flows and in turn also be moved by them. Although undetectable by definition, these unearthly fluids were the intellectual response to Aristotle's instinctive claim that nature abhors a vacuum. Until the 17th century, this type of theory was proclaimed as powerful philosophy, but was never robust enough to make experimental predictions and thus render itself open to the ultimate test of falsifiability. Nevertheless, these concepts were the original field theories.

Building on the empirical evidence compiled by Galileo, Kepler and Tycho Brahe, Isaac Newton in 1686, was the first to describe the world and heavens as consisting of matter alone, whose mobility was apparently controlled by laws which could be precisely described by mathematics. Although not often stated, it can be argued that Newton's greatest achievement was to be the first to distinguish acceleration from velocity in both conceptual and mathematical terms. While it may be debated whether he, or Gottfried Leibniz, was the first to discover differential calculus, it was undoubtedly Newton who first put it to practical use. His laws of motion which described the relationship between mass, force and acceleration were a profound conjecture but not inherently testable until someone proposed the first force law. It was therefore highly convenient that he was also the person who deduced his universal law of gravitation which describes the attraction between all objects in proportion to the product of their masses and the inverse square of their distance of separation. The fact that this law appeared to explain both the orbits of extra-terrestrial bodies as well as the motions of objects on earth, made this equation the most powerful piece of mathematics until that date and maybe still so. Although, not performed in Newton's lifetime, its potency was compounded by the fact that it made accurate predictions of the radial acceleration between masses which could also be weighed statically, thus providing a strong experimental proof of validity. It has now been tested in many environments and while the measurement of G, the Newtonian gravitational constant, is still difficult to pin down precisely, the form of Newton's laws of motion and gravity remain unchallenged in all experiments relating to mass interaction for which the theory was developed. Any single laboratory controlled experiment could still provide evidence that disproves Newton's laws but none has been forthcoming.

It is claimed that Newton was disturbed by the IAAAD nature of his gravitational force law because once in a private letter, he conceded that he nor possibly anyone could understand the required physical mechanism. However this did not prevent him from exploring the mathematics of IAAAD and accepting the suspension of understanding for the benefit of accurate prediction of experiments. He never mentioned in "Principia" that he had any doubt regarding the possibility of distant unmediated interactions.

The IAAAD revolution continued relentlessly until the mid-19th century. During this 300 year period, LaPlace had explored the ramifications of Newtonian gravity and deduced that the interaction between masses must be at least virtually instantaneous or else the solar system would not display the stability we observe. Euler, Lagrange and D'Alembert among others all developed mathematical methods to increase the ease of utilising Newton's laws for predicting both earth bound and celestial motions. Before the end of the 18th century, John Michell and Augustin Coulomb had proposed and tested two new Newtonian inverse square force laws of attraction and repulsion between magnetic poles and isolated charges respectively. Scientists by this time were completely entranced by the simplicity and universal nature of the form of the Newtonian force laws which produced equal and opposite forces on two interacting particles along the line joining them. In this manner, the highly valued principle of the conservation of momentum was always guaranteed to be satisfied. It was therefore natural to continue the search for other force laws which displayed the same mathematical form.

In 1820, the final chapter of IAAAD discovery commenced as well as the very early traces of a return to the modern era of physics which would again become dominated by the invention of undetectable fields to fill the void between matter. In Copenhagen, Hans Christian Oersted demonstrated that an electric current had a direct effect on a compass needle. News of this discovery passed quickly to Paris and within a few weeks, several further discoveries were announced. Andre Marie Ampere had been inspired by Oersted and had found that two current conductors display an attraction or repulsion depending on their relative current direction. This led a few years later to the publication of his force law describing the Newtonian inverse square attraction or repulsion between small sections of current carrying conductor which he called current elements. This became the fourth IAAAD Newtonian force law and in Maxwell's treatise 50 years later was hailed as the cardinal law of electrodynamics. It has absolutely no connection to the Maxwellian law inaccurately known as "Ampere's Circuital Law". Also in 1820, Biot and Savart presented a mathematical equation which described the magnetic field as a function of nearby electric current, which they proposed as the mechanism that guided Oersted's compass needle.

As a result of the discovery of electromagnetic induction by Michael Faraday and independently, by Joseph Henry in the early 1830's, the race was on to tie together the novel features comprising the fledgling subject of electromagnetism. In Germany, Franz Neumann and then later Wilhelm Weber and Gustav Kirchoff took their inspiration from the IAAAD Ampere force law. Neumann developed the concept now called the vector potential and when the dot product was taken with an Amperian current element it led to his expression for the potential energy between any pair of current elements. Partial differentiation of this potential with respect to distance led to the Ampere force and with respect to time led to both the dynamo and transformer electromagnetic induction effects. Although Neumann never explored it, partial differentiation with respect to the two independent angles in the equation reveals forces which attempt to rotate the current elements. It has been proposed, but not yet fully demonstrated, that this could be the IAAAD mechanism that lies behind the effects that we now ascribe to electromagnetic radiation.

Weber theorized that a charge neutral Amperian current element comprised flows of negative and positive charges in opposite directions and developed a single force law which combined the predictions of both Ampere's and Coulomb's force laws. In his derivation, he was forced by dimensional analysis to create a constant which he called C. It had units of distance over time and could be measured by comparing the electrodynamic work that could be achieved by discharging a known amount of electrostatically stored energy. This measurement of C turned out to be related by a factor of $\sqrt{2}$ to the quantity that we now call the speed of light, c. Weber realised that his force law predicted that C was the velocity at which two charges moving toward each other would experience zero force as result of a precise cancellation of the Coulomb and Ampere force. This was an absolutely extraordinary prediction for the year 1856. Weber could hardly have foreseen the particle accelerators of the future, but we are all now acutely aware that however much voltage is applied to a free charged particle, its velocity is observed to approach but never exceed c. The accepted modern understanding of this phenomenon is that the mass of the accelerated particle is constantly increasing as a prediction of Einstein's field theory of Special Relativity (SR) and as its velocity approaches c, the mass tends to infinity and the particle is thought to gain energy with negligible increase in velocity. Weber's IAAAD law which has been shown to be accurate at low charge velocities may have a subtle high velocity modification that predicts that the net force on a charged particle goes to zero as its velocity approaches c with no further gain in energy. Our modern conviction that the particles, which race around the accelerators of CERN and other labs, possess very high energies, stems from the difficulty of slowing them down. However all particle deceleration is also caused by electromagnetic interaction and thus the Weberian type deceleration forces may well be negligible until the relative velocities become significantly slower than c giving the illusion of enhanced energy. The mathematics of these two wildly differing and yet each self-consistent mental models is not sufficient to determine which depicts reality. We also presently have no experimental basis to determine whether mass increases or total electromagnetic plus electrostatic force decreases as a particle approaches the speed of light. Therefore the search continues to find situations which may distinguish whether the field or the IAAAD paradigm more accurately represents the truth.

There is a very important difference between the IAAAD and field theory paradigms. IAAAD theories predict that the interactions and forces between physical objects are directly observable and are therefore subject to the falsifiability tests required by the scientific method. In contrast, field theories make predictions about quantities at points in empty space. The only way to check whether these predictions are accurate is to place a detector in that space, but then one is only testing a mathematical theory which is indistinguishable from an IAAAD matter interaction theory. So field theories are inherently unfalsifiable and therefore should be ruled out simply on the basis of the scientific method. However, the history of science has shown that most physicists are swayed by the romance of field theory and suspension of the scientific method has unfortunately become the norm.

The next major contributor to the subject of matter interaction in the mid 19th century was James Clerk Maxwell. While he proposed his new theory of electromagnetic wave propagation in the mid 1860's, his balanced views were most thoroughly expressed in his two volume treatise published in 1873. Although he confessed to have taken Faraday's field conceptions as the inspiration for his theory of electromagnetic waves, he similarly expressed supreme respect for the science of the "Germans" (Neumann, Weber, Kirchoff, Helmholtz etc.) and their highly accurate IAAAD mathematical models. He recognized that his field theory which could explain both induction and wave propagation lacked a ponderomotive force law and suggested that of all possible candidates, Ampere's law was by far the best as it was the only one that would preserve Newton's third law of balanced action and reaction. The only other candidate force law that Maxwell gave any consideration was proposed originally by the German high school teacher and inventor of the vector cross product, Hermann Grassmann. It is therefore not surprising that Grassmann proposed a triple vector cross product law that was based on IAAAD forces between Amperian current elements. The mathematics was spectacularly modern but the net result was a force law which did not predict equal and opposite forces on the two elements. Maxwell discussed this law at length, but ultimately rejected it. Nevertheless in conjunction with the Biot-Savart law defining the magnetic field due to current, the Grassmann law has become the magnetic component of the modern Lorentz force law, usually described as "J cross B". It begs the question, is it Maxwell or his field theoretician followers who made a mistake and backed the wrong force law.

Unfortunately Maxwell died prematurely in 1879 aged only 48 without anybody truly understanding his novel electromagnetic field theory. It consisted of 20 equations and 20 variables, was based on Neumann's IAAAD vector potential as the primary field concept and included an IAAAD force law. His theory was therefore truly a jumble of field theory and IAAAD mathematics, and as a consequence was never exploited in the form in which he left it. The famous four "Maxwell's equations" were instead extracted from his treatise by a group of primarily British scientists, often referred to as the Maxwellians. Oliver Heaviside, the most outspoken of this group, ruthlessly, openly and without justification, removed the Ampere force law and the Neumann vector potential from Maxwell's theory in 1888. He did this to arrive at a set of equations that could provide a simplified system of field quantities that would interact in such a way as to provide the propagation of the electromagnetic waves that are accepted and taught today.

The Maxwellians were highly motivated by the late 19th century British engineering monopoly in the field of submarine telegraphy. Ironically, the work of these physicists ultimately led to the development of radio communications which had the effect of breaking the British economic stranglehold on international communications. Nevertheless, Heaviside was well aware that Gustav Kirchoff had exploited the IAAAD Weber force law to develop the equations of transmission line theory 30 years earlier in 1857 including the concept of magnetic permeability. In this manner Kirchoff predicted that the speed of propagation of voltage pulses along long conductors was a function of the capacitance and inductance per unit length and was equal to Weber's constant c, which we now call the speed of light. However in Kirchoff's theory there were no travelling field quantities, only the IAAAD interactions between distant current elements. In other words, every current element in the whole line, even the ones at the very end, starts to respond as soon as a signal is fed into the line. It is simply the inverse square force strength, the inertia of charged particles due to their mass and the mind boggling complexity of many body simultaneous interactions that makes the illusion of energy propagation a mathematical possibility. Heaviside was apparently unwilling to accept that energy propagation was an illusion and his perseverance in creating the modern Maxwell's equations and arguing for the reality of electromagnetic fields can be interpreted as much as a consequence of nationalistic pride as a search for scientific understanding.

A few years prior to Heaviside's publication of his revision of Maxwell's theory, other scientists became aware that if a movement away from IAAAD physics was to take hold, then these newly proposed electromagnetic fields would be required to support and transfer energy and momentum. In 1884, both Heaviside and John Henry Poynting independently deduced the existence of a vector ($\mathbf{S}$=$\mathbf{E}$x$\mathbf{H}$) which describes both the flow of energy from a radiation source to a detector as well as from a power supply to the remainder of an electrical circuit. Since Poynting was the first to publish, this quantity is now always referred to as the Poynting Vector. The vector represents an energy flux density meaning the amount of energy per unit time passing through unit area. Since electromagnetic energy was now known to always travel at the speed c, there was a consequent field momentum flux density ($\mathbf{S}$/c) which represented the momentum per second passing through unit area. With the technology of the day, these quantities were untestable, but they have become an integral and inevitable part of modern electromagnetic field theory.

Heaviside's field equations had a rocky start in the early 1890's when it was discovered that they were not Galilean invariant for all observers. This meant that one could detect one's velocity by making measurements of the local field quantities which meant that the laws of physics would depend on the motion of the observer which is considered to be unacceptable. Hendrik Lorentz using mathematics proposed by Henri Poincare and George Fitzgerald proposed a set of transformations that distort space and time as a function of observer velocity in just such a way that the laws of physics again become the same in all inertial reference frames irrespective of their velocity. Lorentz also recognized that a complete field theory required the adoption of an electromagnetic force law and made a case for promoting Grassmann's non-Newtonian law and incorporating it with Coulomb's Newtonian IAAAD law into the now well known Lorentz force law ($\mathbf{F}=q(\mathbf{E}+\mathbf{v}\times\mathbf{B})$). The stage was therefore set for Einstein in 1905 to propose his theory of special relativity which gave a theoretical basis for the Lorentz transformation by proposing the untestable assumption that the speed of light was c for all observers.

Since 1905, there has hardly been any opposition to the Maxwell – Heaviside – Poynting – Lorentz – Einstein theory of electromagnetic force, induction and radiation. As a result, no student for over 100 years has been exposed to the IAAAD theories of electromagnetism other than as a matter of history. However there are a few outstanding experimental issues which are at complete variance with the modern paradigm. These results can be described as the existence of longitudinal electrodynamic force and the failure of the Poynting vector to supply sufficient momentum to explain the magnitude of measurable electromagnetic force.

Ampere's law has been known to predict electrodynamic tension in conductors since it was first proposed in 1822. It was not easy to prove with the small currents available in the early 19th century, however by the early 1900's, an engineer named Carl Hering was incorporating these forces to pump liquid metal around smelting furnaces without the use of external magnets. Longitudinal electrodynamic forces in the direction of current flow have now been demonstrated in the laboratory in the guise of exploding wires, recoil forces in railguns and a series of experiments specifically designed to test the accuracy of the Ampere force [1]. Lorentz and Heaviside felt able to justify ignoring the longitudinal component of the electrodynamic force because it can be shown that a current element when interacting by Ampere's force law with a complete external current loop only experiences a purely transverse force equal to the Lorentz force. However, a current element when interacting with only the elements in its own circuit can experience a longitudinal force component which can lead to movement if the circuit is flexible. This motion is completely ignored by the Lorentz force which is therefore invalid.

An even greater indictment of the modern prevailing field theory is the failure of the Poynting vector. It is currently taught that in an electrical circuit, power does not leave the power supply through the current conductors, but rather permeates through the insulating space between the conductors in a manner consistent with the Poynting vector mathematics. The power contained in the field then re-enters the conductors at all points of the circuit providing the energy to drive the current at that location which is then dissipated as Joule heat at the same place. This theory therefore predicts that all the power that leaves the power supply disappears as heat, leaving no extra power to perform mechanical work if for instance the circuit happens to be an electrical motor. The situation is even more striking in the case of the induction motor. In this situation, the stationary coils, connected to an external power supply, are referred to as the stator coils and the mobile rotating coils make up the rotor. The varying current in the stator coils induces currents in the rotor coils and the resulting electromagnetic force between the two sets of coils causes the rotor to spin and drive a mechanical load. Since there is no electrical connection between the stator and rotor coils, all of the electromagnetic momentum and energy must pass through the closed surface that surrounds the rotor coils. By knowing the torque that the motor applies to the load, the amount of momentum that must be applied to the rotor coils per second can be deduced. The Poynting vector theory which relates momentum flux density to energy flux (power) density across a given surface area therefore predicts the amount of electromagnetic field energy which must be entering the rotor per second which is in units of power. It turns out that for any standard induction motor, this field power requirement is 6 to 7 orders of magnitude greater than the power that is actually being supplied to the motor. In other words, the mathematics of the Maxwell – Heaviside – Poynting – Lorentz – Einstein field theory cannot explain the power transfer in the most mundane of electrodynamic experiments, the induction motor which was invented by Nikolai Tesla in 1887 at about the same time as the proposal of the Poynting vector. It is almost unbelievable that in 130 years, nobody has been troubled by this glaring failure of field theory. When a field theory is unable to provide the field amplitude that it requires for self-consistency then it ceases to be a valid field theory and one must seek an IAAAD explanation for the observed phenomena.

It appears therefore that the induction motor is an inherently IAAAD device and now heralds the return to at least a reinvestigation of the validity of the IAAAD paradigm with respect to all of the experiments that have taken place since it was confined to oblivion by Heaviside and others in the 1880's. We certainly know that the laws of Ampere, Neumann and Weber are able to explain all electromagnetic force and induction phenomena, but it is not yet clear whether these laws can explain the effects that we currently ascribe to electromagnetic radiation. However if we follow the mathematics that Kirchoff used to describe the performance of transmission lines, then we know that the speed of propagation is related to the inductance and capacitance per unit length of the line. As the separation of the conductors of the line increases the inductance per unit length increases and the capacitance decreases in such a manner that the speed of propagation will tend towards the speed of light in free space. Since IAAAD physics involves the simultaneous interactions of all objects in the universe, then although much of the universe is very far away, there is still a lot of it out there and it may be that the universe unwittingly conspires to be the guiding elements for every accelerating charge which we would now call a radiation source. Early calculations [2] demonstrate that this methodology may well provide a theory of "no light" that explains all of the existing optical, radio and other "electromagnetic radiation" effects, but it is still an open question. One of the reasons this work has not been done by the earlier 19th century IAAAD theorists is that it will require computers to model the many body simultaneous interactions which was simply not possible with purely analytical mathematics.

Despite Einstein's claims that IAAAD theories were too "spooky" to be real, it seems there must inevitably be a return to this form of physics which does not ascribe values to undetectable fields. The human mind is limited and therefore may always feel uncomfortable about simultaneous interactions across infinite distances, but at least we have a mathematical system that can handle the spookiness. Therefore there is no impediment to exploiting IAAAD theories to resolve a host of current failures and paradoxes that field theory and Special Relativity have generated. IAAAD physics has already thoroughly permeated the subject of quantum mechanics in the guise of Bell's inequalities, the Aharanov-Bohm effect and the concept of entanglement. Consequently Instantaneous Action At A Distance mathematics and philosophy will soon be seen as the obvious norm and people will wonder again why we dabbled so long with field theory. It will inevitably provide novel insight to develop new theories which will be more robust than existing ones as they will be subject to the experimental falsifiability tests of the scientific method.

[1] P. Graneau, N. Graneau, "Newtonian Electrodynamics", World Scientific, Singapore, 1996

[2] N. Graneau, *Have You Seen the Light?*, Chapter 8 in "Instantaneous Action at a Distance in Modern Physics: Pro and Contra", Nova Science, Commack, New York, 1999