Inertial Common Time – Ernst Mach and the Dilation/Contraction Scam

According to Aristotle, the natural dynamical state of a body is to be at rest. In the early seventeenth century, Galileo overturned that doctrine in advancing the interpretation that a body in linear motion will remain in that motion until a force acts upon it. Furthermore, the laws of motion will be the same within any frame of reference that is moving at a constant velocity, a so-called inertial reference frame. Near the end of that century, Isaac Newton laid out his three laws of motion to formally establish the field of classical mechanics. He observed that each of those laws only characterizes the relative motion of bodies, implying that there was no underlying assumption regarding the existence of a distinct absolute reference frame of space. Nevertheless, Newton continued to puzzle over the conceptual plausibility of a potentially undetectable absolute spatial reference frame.

Around that same time in 1676, Ole Rømer first demonstrated that the speed of light propagation is finite rather than infinite as many had previously assumed. The significance of that observation gained increased significance two centuries later when James Clerk Maxwell introduced his field equations of electromagnetism which served to unify the seemingly distinct phenomena of electrical charge interactions and magnetism. One of the striking deductions from Maxwell's equations was that, in seemingly empty space, the speed of light is apparently the same in any direction. That conclusion caused considerable controversy. On one hand, based upon previous analysis of other forms of wave motion, such as water waves and sound, there has to be a medium through which that wave is propagated. Yet if 'empty space' is actually filled with such a medium for conducting electromagnetic radiation, referred to as the aether, then the speed of light would be expected to differ depending upon whether the source of that light is either stationary or moving, relative to the aether frame of reference.

In 1887, Michelson and Morley designed an instrument that was capable of accurately monitoring whether the speed of light is the same both parallel to and perpendicular to the instrument's direction of travel through the hypothetical aether. No such difference was detected. Starting in 1893, Dutch physicist Hendrik Lorentz published a series of papers which attempted to analyze how the Maxwell's electromagnetic field equations would need to be transformed in order to be valid in different inertial reference frames. In formulating his progression of increasingly accurate transformation equations, Lorentz observed that the magnitude of time and length appeared to differ depending upon the reference frame being used to measure them. Unfortunately, his analysis efforts were significantly confounded by his continued adherence to the assumption of a stationary aether that serves as the absolute reference frame for the transformation equations that he developed. Famed mathematician Henri Poincaré joined in the effort to perfect those formulas and their physical interpretations both through his private correspondence with Lorentz and by his own independent publications. Most crucially, in 1899 Poincaré asserted that electromagnetic interactions must satisfy the same relativity principle that Isaac Newton had earlier established for classical mechanics – the physical interactions must depend upon only the relative motion of the bodies involved (Darrigol, 2004). This conclusion directly implied that any hypothetical absolute reference frame must be physically undetectable by such measurements. By 1905, Poincaré had successfully revised Lorentz's transformation equations so as to satisfy his self-described Principle of Relativity.

The Lorentz transformation equations appeared to offer the basis upon which an observer in one inertial reference frame could deduce what physical dynamics another observer would see from a different inertial reference frame, needing only to know the relative velocities of those two reference frames. The potential complication to gaining that level of insight is the need to know the time in that second inertial reference frame, that is to say, whether the clocks within those two inertial reference frames can be mutually synchronized. Given his position as a senior official within the French government's Bureau des Longitudes, Poincaré was keenly aware of the critical role that clock synchronization then played in the process of determining longitude for ships at sea. He formally analyzed the standard procedure by which telegraph operators would synchronize the local time at their sites. By timing the interval between sending a message and receiving the promptly returned response, the time of arrival at the distant site could be assigned as the midpoint of that time period. Observing that such an analysis assumes that the rate of signal propagation must be the same in both directions, Poincaré recognized the seemingly unsurmountable challenge of measuring the speed of light in a single direction. This led Poincaré to conclude that the premise that light travels at the same speed in any direction in every inertial reference frame must be treated as a postulate in his developing theory of dynamics.

Before further examining Poincaré's analysis, let us first consider the concept of an inertial reference frame in more detail. Textbook discussions of reference frames often present the standard plot of the three perpendicular x, y, and z axes which all pass through the origin where the values of those three coordinates are

(0,0,0). Within that reference frame, the progression of a dynamical process can then be displayed by a series of (x,y,z) coordinate values that change as a function of time. A second inertial reference frame might then be similarly displayed by being initially superimposed upon the first and then subsequently sliding along the x axis at a constant rate. With respect to that second reference frame, the x axis coordinates of the dynamical process will be shifted by the magnitude of separation between the origins of the two reference frames.

An inertial reference frame can be usefully characterized by two properties. At a basic level, it is a set of points in space for which local clocks at each point can be mutually synchronized via Poincaré synchronization, a procedure which is now conventionally misattributed to Albert Einstein. Applying the Poincaré synchronization procedure to each clock within the inertial reference frame, a light signal is sent to a reference clock and then immediately reflected back. By dividing the total travel time of that signal by a factor of two, the time at which that signal arrived at the reference clock is calibrated. This synchronization procedure can then be carried among a subset of the other combinations of clock pairs to insure that the distances between all pairs within the reference frame are determined. To establish the second key property of an inertial reference frame, this entire procedure is then repeated. If identical results are obtained both in terms of the synchronization to the reference clock and for the travel times of the various light signals, this indicates that the distance spacing between all pairs of the clocks has remained unchanged.

While inertial reference frames are typically specified in other terms, this characterization draws attention to a common misunderstanding. Dynamics problems are often described in terms of an object traveling at a specific velocity in an inertial reference frame. What is implied, but often overlooked, is the fact that the more appropriate description is of an object traveling at a specific velocity with respect to an inertial reference frame. As indicated by the Poincaré synchronization criterion described above, an object that is moving with respect to a given inertial reference frame cannot be an element of that reference frame. In turn, the reference frame in which that object is stationary is conventionally referred to as the stationary reference frame. It is crucial to keep in mind that, in an operational sense, the transformation equations developed by Lorentz serve to map the two inertial reference frames onto each other. The dynamics of the moving object are unaffected, only the perspectives of observers in the two different reference frames are altered.

Since this Poincaré synchronization criterion can be applied to every possible inertial reference frame, every clock within each such reference frame can be synchronized with respect to the other clocks within that reference frame. An obvious question then becomes whether different inertial reference frames can be synchronized on a pairwise basis. Imagine applying the Poincaré synchronization procedure to two clocks located in different inertial reference frames, both frames having been internally synchronized. A light signal sent out from clock A in the stationary inertial reference frame A will reach clock B in inertial reference frame B and will be immediately reflected. Since the instantaneous reflection process will be insensitive to the relative motion of the two reference frames, the return transit time to the clock A will be equal to the initial transit time, and thus the mutually determined arrival times can be synchronized between the two different inertial reference frames. If that Poincaré synchronization protocol is then repeated between the two different inertial reference frames, the mutual clock synchronization will be reaffirmed. On the other hand, the relative motion of these two inertial reference frames will result in the light transit times being altered between the two sets of observations in a manner that directly indicates the relative velocity of the two reference frames. By the symmetry of the analysis, we can be assured that repeating this synchronization process treating inertial reference frame B as the stationary source of the light signals will yield identical results. This analysis implies that dynamical processes which give rise to different perceptions when viewed from different inertial reference frames can be interpreted through the Lorentzian transformations on a common time scale.

By the time that Albert Einstein published his initial paper on Special Relativity in the fall of 1905, Lorenz and Poincaré had presented a set of publications which describe various aspects of the Lorentz-Poincaré relativity theory. In particular, Poincaré had demonstrated that the Lorentz transformation formulas represent correction factors which enable the data received in the detector reference frame to be interpreted in terms of the events as they were seen to occur within the reference frame of the source. Shortly thereafter, Poincaré introduced the four dimensional space-time (x,y,z,ict) where i is $\sqrt{-1}$ and c is the speed of light. In this analysis, he demonstrated that this space-time exhibits the formal properties of a mathematical group which he humbly named the Lorentz group. That space-time group would provide the mathematical structure within which both Special and General Relativity would be analyzed. The sum of $x^2 + y^2 + z^2 - (ct)^2$ is a constant within this space-time group. Therefore, although there are four space-time variables, the specification of any three variables determines the fourth. Hence, in terms of mathematical degrees of freedom, this is still operationally a three dimensional level of complexity.

So what is it about Einstein's 1905 paper that led to his extraordinary level of fame while, in contrast, Henri Poincaré has largely faded into the dustbin of history? That question surely intrigued science historian

Sir Edmund Whittaker who in 1953 wrote “Einstein published a paper which set forth the relativity theory of Poincaré and Lorentz with some amplifications, and which attracted much attention” (Whittaker, 1989, p. 40). Not surprisingly, Whittaker was harshly chastised for his minimization of Einstein’s alleged originality. A far more typical approach to this topic was offered by famed mathematician and physicist Roger Penrose in his delivering a spectacularly backhanded compliment to Poincaré by noting his achievements “in building up the essential mathematical structure of special relativity in the years between 1898 and 1905, independently of Einstein’s fundamental input in 1905” (Penrose, 2016, p. 417). It is rare indeed that one needs to be credited for the honor of intellectual independence in their discoveries with respect to others who report those same results at a later date. Perhaps, in the world of relativity in both time and politics, we should take comfort in the fact that Henri Poincaré was never formally charged with having plagiarized the future writings of Einstein.

Yet exactly what was the “fundamental input” that Einstein provided to this process? Fortunately, Einstein himself answered that question (Logunov, 2005, pp. 27-28):

“One had only to realize that an auxiliary quantity introduced by H. A. Lorentz, and named by him “local time”, could be defined as “time” in general. If one adheres to this definition of time, the basic equations of Lorentz’s theory correspond to the principle of relativity”

Stated in more direct terms, the time signals one receives from another inertial reference frame should not be treated as signals that have been distorted by the effects of the finite rate of light propagation which are to be corrected by the Lorentzian transformations. Rather, from the solipsistic perspective of Special Relativity, the signals received in the observer’s frame of reference are the only reality. To fit this conceptually myopic perspective, the physical reality within the other frame of reference must be assumed to be transformed to match.

How are we to understand the physical justification for Einstein’s solipsism? The basis for this extraordinary assertion lies in a single line from Einstein’s paper (Einstein, 1923):

“So we see that we cannot attach any *absolute* signification to the concept of simultaneity”

As later succinctly summarized by the famous mathematician and physicist Herman Weyl (Logunov, 2005, p. 50):

“we are to discard our belief in the objective meaning of simultaneity; it was the great achievement of Einstein in the field of the theory of knowledge that he banished this dogma from our minds”

Given the extraordinary importance attached to Einstein’s claim of no *absolute* significance for the concept of simultaneity, one might naively assume that there would be great intellectual interest in how Einstein managed to ‘prove’ that claim. Yet as science historian Arthur I. Miller wrote in his celebrated intellectual biography of Einstein’s development of Special Relativity theory, “As far as I know Einstein’s demonstration in §2 [section 2] of the relativity of simultaneity is rarely analyzed” (Miller, 1998, p. 192).

Einstein’s ‘transformational’ insight was based upon an alleged demonstration that it is impossible to self-consistently synchronize the clocks from two different inertial reference frames, and hence a common time cannot be established between these two reference frames. In his ‘proof’, Einstein describes a stationary inertial reference frame in which a rod of length l is positioned with a clock placed at each end (Einstein, 1923). Both the clocks within the inertial reference frame and those at the ends of the rod are synchronized by the Poincaré synchronization procedure. The rod and its attached clocks are then accelerated to a constant velocity. A second round of ‘synchronization’ is then performed on the two clocks at either end of the moving rod. Yet rather than utilizing the Poincaré synchronization procedure which applies synchronization initiated from a clock within the stationary inertial reference frame of the moving rod, Einstein calculated the transit time for the light signal traveling between the ends of the moving rod as it nominally appears from the perspective of the initial stationary inertial reference frame. Not surprisingly, the resultant ‘synchronization’ procedure failed. Einstein’s misapplication of Poincaré synchronization is rendered thoroughly transparent by the fact that in one direction the apparent speed of light that he derived is greater than c, a result that is fundamentally incompatible with the Lorentz transformation equations.

How did Einstein come to propose such a clearly flawed ‘disproof’ of Poincaré’s interpretation of the Lorentz transformations, and more significantly, why did the orthodoxy of physics come to so fervently embrace such an erroneous analysis? The answer to that question lies in the origin of modern physics. Textbooks tell us that the era of modern physics began in 1900 with Max Planck’s discovery of the quantum effect in his blackbody radiation measurements. This was then followed five years later by Einstein’s analysis of the quantization of energy in the photoelectric effect and his more famous Special Relativity paper. In reality, the era of modern physics had begun two decades before.

Not long after the initial excitement following the publication of Maxwell's electromagnetic field equations in 1865, a sense of frustration spread throughout the physics community. When combined with the well-established field of Newtonian mechanics and the more recently introduced field of thermodynamics, Maxwell's characterization of electromagnetic interactions appeared to indicate that all of the most important questions of physics had been largely, if not completely addressed. In a particularly relevant illustration from the 1870s, the University of Munich physics mentor of the then young Max Planck counseled him against going into physics as a career, telling him that "In this field, almost everything is already discovered, and all that remains is to fill a few holes" (Lightman, 2005, p. 8). To add insult to injury for the widely perceived closing field of physics, the late nineteenth century became dominated by the increasingly rapid rate at which discoveries in physics were transformed into practical applications in engineering. The long celebrated aura of intellectual prestige among physicists appeared to be nearing an end as they were being reduced to the status of handmaidens to the magnates of the Industrial Revolution.

Yet a more profound response to this challenge was being formulated by Ernst Mach. While more widely known for his work on sonic shock waves, Mach's historical significance comes from his efforts to explicitly redefine the philosophical role of physics. From Mach's perspective, the fundamental flaw of Galileo's causality-based 'understand-reality' approach to science is that it attempts to overcome the conceptual challenge of bringing coherence and correspondence to the differences in the world as we perceive it and the world as it actually exists. When as operationally straightforward as are Newton's three laws of mechanics, such understand-reality science can directly empower those who Plato referred to as the *Cattle*. While Maxwell's equations were surely less intuitively understandable, the rapid commercialization of the electrical power industry had undercut the role of electromagnetic theory as the exclusive badge for the intellectually transcendent. As dramatically summarized in Plato's famed story of the dancing shadows on the wall of the cave (*Republic*), the *Cattle* cannot and should not be allowed to understand the world of illusory perceptions in which they are trapped. It is the exclusive opportunity and obligation of the *Best* to see beyond the illusion of those dancing shadows and to guide society accordingly.

In drawing an analogy to the papal threat that Cardinal Bellarmine famously delivered to Galileo, historian of science John T. Blackmore observed that "Mach's greatest success as a philosopher was to persuade several generations of philosophically inclined scientists to abandon Galileo's understand-reality science for an updated version of Bellarmine's describe-and-relate-the-appearances science" (Blackmore, 1972, p. 170). The *Cattle* are only to see the connections between the events of their perceptions accordingly to the lines that the *Best* have drawn for them. With no papal dogma to call upon, Mach was confronted with the challenge of defining a doctrine of faith and an admission policy for entrance into his 'Church' of modern physics. The Machian faith was to be founded upon the principle of weaponized empiricism. By denying the validity of any alternative source of understanding for the significance of empirically observed perceptions, the Machian faithful would create a politically self-affirming set of authoritative interpretations for such observations that is superficially dressed in the costume of naïve empiricism.

Of central importance to Mach's own approach to this challenge was the still contended issue of the existence of atoms and molecules. While speculated about since the days of ancient Greece, at the end of the nineteenth century there still remained no way to directly observe the existence of atoms. This issue was particularly significant to Ernst Mach as he had decided to use the axiomatic formalism of thermodynamics as his paradigm for creating a more general 'describe-and-relate-the-appearances' approach to science. Since thermodynamics was developed for the purpose of characterizing the basic properties of bulk materials, the possibility of a more fundamental science based upon the atoms of those materials represented a fundamental threat. Most relevantly, that threat had emerged in the form of Ludwig Boltzmann's theory of statistical mechanics.

James Clerk Maxwell's kinetic theory of gases had enabled him to deduce the distribution of different velocities for the molecules within a sample of gas. Boltzmann not only generalized the concept of the Maxwell-Boltzmann distribution, he developed the seminal idea that there exists a logarithmic mathematical connection between probability and the thermodynamic concept of entropy. This establishment of the field of statistical mechanics underwrote the conclusion that the laws of thermodynamics could not be regarded as being absolute in a logical sense. Rather they are the result of strongly biased statistical distributions among atoms and molecules.

The emerging field of statistical mechanics was deeply offensive to Ernst Mach. He saw the absolute truth of thermodynamic deduction as being under assault. Furthermore, the field of physics was being polluted by the empirically unobserved inventions of the atom and the molecule that had been imported from the lowly subject of chemistry. By the end of the nineteenth century, Mach had succeeded in building up a nearly cultish following among a substantial fraction of German-speaking physicists as well as a considerable number of adherents across the world of physics more broadly. Mach efficiently turned that level of political support into a highly personalized long-running attack upon Ludwig Boltzmann and his scientific accomplishments which, in turn, helped secure the political stridency of the Machian faithful. While it remains a matter of debate how much this prolonged vendetta by the Machian faithful contributed to Boltzmann's decision to commit suicide in 1906, there can be little doubt that, three decades after his initial brilliant establishment of the field of statistical mechanics and its intimate connection to thermodynamics, the political desecration of his professional career surely took a severe emotional toll.

At its most basic level, Machian philosophy is focused upon the capture of language. As so dramatically demonstrated during the political unfolding of Special Relativity, two fundamentally different linguistic representations of reality can give rise to the same set of observable predictions. Which of these two representations came into general use was strictly a political decision. Einstein came into intellectual maturity as a physics student during the era in which the philosophical doctrine of Ernst Mach dominated the German-speaking world of physics. This intellectual domination extended to Zurich which became a major Machian stronghold. Einstein became an active member of Zurich's so-called Mach colony. Einstein repeatedly acknowledged the impact that his earlier reading of Mach's *The Science of Mechanics* had on his view of physics and wrote that "it is justified to consider Mach as the precursor of the general theory of relativity" (Pais, 2005, p. 283). Despite having been unable to secure a university faculty appointment in physics, Einstein's ongoing extensive direct interactions with the leading journal *Annalen der Physik* had already demonstrated "an impressive mastery of the contemporary literature" well before 1905 (Logunov, 2005; Popper, 1966).

In striking contrast, up until his death in 1955 Albert Einstein continued to insist that he was unaware of Poincare's research previous to the publication of his 1905 Special Relativity theory paper (Miller, 1998). It should be noted that Einstein was still issuing such disclaimers two years after Sir Edmund Whittaker's pointed reassessment of the intellectual origins of relativity theory. In arguably Einstein's most flagrant dismissal of his intellectual debts, it is well-known that in the years before his initial relativity paper in 1905, he belonged to the informal "Akademie Olympia" study group of fellow physicists, which included his friend Maurice Solovine. This group carefully studied Poincaré's 1902 book *La Science et l'Hypothèse*. As Solovine later described the experience of their studying Poincaré's book, it "profoundly impressed us and kept us breathless for many weeks" (Darrigol, 2004). In this book, Poincaré stated that "I consider it very probable that optical phenomena depend only on the relative motion of the material bodies present … *exactly*." Poincaré then presented the principle of relativity for which he conjectured that any violation of that principle could never be detected empirically, and therefore its analysis must be treated as an a priori postulate. Poincaré's book also explicitly asserted the experimental indetectability of the aether, and he predicted its eventual abandonment as a no longer useful hypothesis, stating that "no doubt, someday the ether will be thrown away as useless" (Darrigol, 2004).

Having entered the field of relativity after Lorentz had already published his final nearly accurate version of the transformation equations and Poincaré had completed that effort, Einstein was well positioned to introduce a different perspective. While Lorentz and Poincaré had long worked to demonstrate that Maxwell's electromagnetic field equations could be interpreted in a fashion consistent with Newton's assertion of relativity within classical mechanics, Einstein could now state that conclusion as an accomplished fact. Furthermore, the transformation equations of Lorentz and Poincaré had made it abundantly clear that it is the constancy of the speed of light that had determined the final form of those equations. Whether Einstein had direct access to Poincaré's final version of those transformation equations or had instead recognized the residual error in Lorentz's final attempt is largely beside the point. The postulates of dynamic relativity and constancy in the speed of light would be sufficient to derive the Lorentzian transformations.

With the discovery of both the quantum effect and relativity, the Machian faithful quickly abandoned their Leader's fixation on thermodynamics and atomic denialism and turned to these two new fields for imposing their political philosophy. For the gravity-only universe of Einstein's General Relativity, all bodies undergo continual acceleration and thus the direct relevance of inertial reference frames largely disappears. Since the local time within an accelerating reference frame is intrinsically dilated with respect to the inertial common time, synchronization of clocks between such reference frames becomes problematic. Thus the erroneous assertion in Einstein's 1905 paper was granted the appearance of having been vindicated, and both he and the Machian faithful then moved on as if no misrepresentation had been committed.

In 1927, less than two years after the initial introduction of quantum mechanics theory, the Machian faithful Max Born and Werner Heisenberg solemnly declared that "we consider quantum mechanics to be a closed theory, whose fundamental physical and mathematical assumptions are no longer susceptible to any modification" (Bacciagaluppi & Valentini, 2009, p. 408). As this emerging political philosophy crystallized into the so-called Copenhagen School, these faithful have been described as having "out-Mached Mach" in their efforts to restrict the range of methodological approaches that would be politically tolerated (Blackmore, 1972, p. 314). Specifically, the concept of physical causality was explicitly excluded. It became forbidden to even speak or think in terms of empirically observable physical states preceding the occurrence of a measurement. Rather, the physical system being measured must be described as remaining in a statistical blur of unobservable quantum states up to the moment of measurement at which time this set of unobservable quantum states collapses down into a single observed physical state. While in common practice, many of the political strictures laid down by the Copenhagen School are now often discretely ignored, the philosophical stench of that dogma still hangs over the field. In many senses the political problem has only become worse, particularly within the preeminent field of elementary particle physics in which the subject appears to have been largely closed for the past fifty years. With seemingly little new to empirically discover, the field has become effectively trapped in a contest over which version of the prediction-incompetent string theory might offer the maximal political benefit for the *Best*.

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