Einstein's Big Break: On the Miracle Year of 1905

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At the end of the nineteenth century, physicists declared their science complete. The mechanics of matter was well understood: according to Newton’s laws of motion and researchers’ models, the dynamics of fluids, optics, and sound waves were growing more refined. James Clerk Maxwell had recently formulated the propagation of electromagnetic waves in four relatively simple equations. Driven by mathematical formalisms, he derived relationships between traveling electric and magnetic disturbances that defied any simple physical explanations but seemed to precisely describe experimental phenomena. This was not to say there was not work to be done but most physicists believed future progress would mainly consist of experimental refinements and more precise measurements of the universe’s fundamental constants.

Within the first decade of the twentieth century, however, physicists found themselves struggling to understand the most fundamental features of the universe including the shape of space, the meaning of time, the characteristics of matter, and the nature of light. Instead of putting the finishing touches on a grand edifice of completed knowledge of the universe, twentieth century physicists were consumed by a race to disassemble that very system and find some stable ground on which to rebuild. This radical reversal was neither easy to begin nor simple for great minds to accept but, once its necessity was realized, new fields of possible knowledges were opened to science.

This jolting beginning to modern physics was not a transition that logically followed from the knowledge of a triumphant classical physics but rather a radical discontinuity with what came before. In 1905, Albert Einstein, an unknown German physicist working as a patent examiner in Bern, published a series of short papers on Brownian motion, the quantum nature of light, and the electrodynamics of moving bodies in one of the most astounding bursts of creativity in the history of thought. These ideas, after years of laborious theoretical elaboration, were the start of a major break with the physical knowledge of the past. While Einstein was not able to continue working this break through its continual battle against classical ideology – indeed, he would spend his later years fighting against the very concepts that followed from his discoveries in the miracle year of 1905 – the conjuncture of his reading of nineteenth century physics with the recent physical discoveries of Michael Faraday, Maxwell, and Max Planck and the mathematical formalisms of Bernhard Riemann's non-Euclidean geometry produced a new physical problematic. This problematic permitted the development of quantum mechanics and relativity theory, the cornerstones of the new edifice of modern physics.

An Althusserian reading of modern physics is an interesting project on multiple registers. This paper will argue that quantum and relativity physics is the first truly Althusserian hard science. We can read its birth as a break in the strong sense: the production of a new scientific problematic from a reading of the contradictions, seams, and lacunae in the ideological framework that came before.

Applying this reading to a hard science ("hard science" should be understood in the American sense to mean the study of the structure of the physical world, especially the domains of physics, chemistry, biology, astronomy, geology, etc) provides a unique opportunity to refine the Althusserian notion of science into a concept that is at least provisionally stable and connected with the other epistemological notions of the break, the problematic, the encounter, and ideology. Unfortunately, the scale of this project prevents this single paper from providing closure on any of these issues. Therefore, these arguments should be taken as the first notes for a much larger investigation of physical science.

The founding of modern physics as a science is not the only target of this reading; the content of this new problematic is also particularly Althusserian. In contrast with the idealism of the Newtonian model, quantum mechanics and relativity use concepts that are more fluid to understand the physical nature of the universe. The problematic of modern physics dispenses with absolute referentiality – notions of absolute space, motion, and time lose their meaning in this new problematic – continuity, and linear causality, in favor of relativity's fabric of space-time, quantum mechanics' discretized energy and light, non-Euclidean geometry's field effectivity and fundamental indeterminacy. The Copenhagen interpretation challenged the notions of objective physical reality and transparent experimentation that were previously taken as fundamental ontological assumptions. Finally, quantum mechanics and relativity asserted the existence of absolute physical limits on velocities and energies that eliminated idealist notions of infinite speed and zero energy. Yet this is only the beginning of the list of the intensely strange results of modern physics.

At the end of the nineteenth century, the success of Maxwell's equations thoroughly convinced the physics community that light and electromagnetic radiation traveled in waves. Countless experiments had also produced characteristic interference patterns with beams of light or electromagnetic radiation, allowing researchers to determine the wavelengths of these disturbances. Nevertheless, there were two areas in which classical physics' theoretical understanding of electromagnetism broke down. First, the problem of light propagation led physicists to posit the existence of the ether, a medium that allowed the transmission of light and filled all space. But it proved undetectable. Second, the problem of blackbody radiation (a solid body emits a certain spectrum of electromagnetic radiation depending on temperature) was incomprehensible to the classical theory of light. These difficulties were symptoms of the problems with the problematic of classical physics. The genius of Einstein, however, was not any experimental one. Instead, Einstein was able to refound physics in a truly scientific problematic. He produced a new mode of theoretical practice based on deductive reasoning, which allowed theoretical physics to move ahead of experimentation for the first time. Because his instinctual approach was sensitive to the epistemological concerns of science, Einstein succeeded in effecting a primary break with classical mechanics, rejecting Newtonian idealism, and producing a proper object of knowledge for his new science.

From the Ether to Special Relativity

Classically, waves transmit energy through space by causing vibrations or rarefactions in some medium, such as water, air, or a string. Indeed, the very concept of a wave was unthinkable without some vibrating substance. Since light was known to transmit through a vacuum, physicists were forced to find some vibrating substance that transmitted light, even when a container was apparently "empty." The solution to this problem was to posit the existence of the luminiferous ether, a substance that filled all space and vibrated to allow the transmission of light. The more experimentally observed features of light propagation that were included in this theory, the more outrageous characteristics the ether was required to possess. The ether was required to be a liquid in order to fill space but also incredibly rigid in order to permit light's high frequency vibrations. In order to prevent the disruption of other physical successes such as the calculations of planetary orbits, the ether also had to be invisible, incompressible, and mass-less with zero viscosity.

As Einstein was growing up, the physics community was working tirelessly to somehow detect the ether. The most famous and (un)successful attempt was an experiment conducted by Albert Michelson and Edward Morley in Cleveland, Ohio. The accepted theory posited that the ether filled the entire universe, which meant it was the absolute rest frame of the universe. Since light should propagate at a constant speed through the ether, light should appear to move at a different speed in relation to the Earth as the planet moves through the "ether wind." Michelson and

Morley's apparatus included a semi-silvered mirror that split a light beam and sent it in orthogonal directions before reuniting it at an interferometer. Because one arm of the device should be pointing in the direction of the ether wind, they predicted the light in that direction would take longer to travel through the apparatus than the light traveling orthogonal to the ether wind. Fortunately, no amount of insulation, refinement or adjustment was able to produce any results. But the ether was so essential to the dominant theories of light propagation that physicists continued to struggle to explain the results in terms of newer and more elaborate theories of the ether.

Einstein had struggled with the problem of the ether since his time studying at the Zurich Polytechnic Institute. While he worked with his professors, who were occupied with trying to devise more sophisticated ether-detection methods, he was certainly exposed to Michelson's experimental "failure," among others. But these experimental data had arguably little impact on Einstein; throughout his life, he maintained that his objections to the inclusion of the ether in physics were purely theoretical.[1] In 1899 he wrote to Mileva Maric, his classmate and future wife, "that 'the introduction of the term 'ether' into theories of electricity has led to the conception of a medium whose motion can be described without, I believe, being able to ascribe physical meaning to it.'"[2] This remark reveals the power of Einstein's subtle reading of existing theoretical discourse. Of course the ether equations worked within the logic of classical physics, for it was a theoretically required addition. Yet Einstein was able to work this logic against itself to determine how the

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[1] Walter Isaacson, *Einstein* (New York: Simon and Schuster, 2007), 116-22

[2] Ibid. 115.

stringent requirements placed on the ether produced an artifact that expressed none of the physical qualities ascribed to any real substance.

While the problem of the ether presented Einstein with strong evidence that there were fundamental problems with classical physics, he would later insist it was not the ether that drove his thinking towards the theory of special relativity. Throughout his life, Einstein continually declared that his method was entirely deductive; he relied almost exclusively on abstract thought experiments, though he later included abstract mathematics (non-Euclidean geometry) in his theoretical arsenal. This was a significant departure from the methodology of the time, which counted entirely on experimentation and inductive explanations of observed data. But Einstein thought little of a theory that follows in the wake of experimentation.

"The big advances in scientific knowledge originate in this way only to a small degree," wrote Einstein about induction.[3] Indeed, it was through a faulty inductive approach that physics was sidetracked for nearly a century by the ideological illusion of the ether.

In an Althusserian epistemology, the inductive approach would certainly be dismissed as a harmful empiricist practice. Relying on empiricism risks "being… incapable of making the science progress, since we will be blind to the nature of the real process of the production of knowledges, and will remain in the wake of facts and events."[4] In order to break with the classical problematic, Einstein had to develop a new mode of production of knowledge that worked to shed the ideological

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[3] Ibid. 118.

[4] Louis Althusser, "*Theory, theoretical practice and theoretical formation: Ideology and ideological struggle*" In *Philosophy and the spontaneous philosophy of the scientists and other essays* ed. Gregory Elliott (London: Verso, 1990), 14

assumptions of the past. A true theoretical science, "far from reflecting the immediate givens of everyday experience and practice, is constituted only on the condition of calling them into question, and breaking with them, to the extent that its results… appear indeed as the *contrary* of the obvious facts of everyday life."[5] This effort is not directed only at individually false facts, but an entire system of ideological beliefs (for ideology posits "obviousnesses as obviousnesses") that stands in the way of scientific progress.[6] (A measure of the magnitude of this break with induction: it took Einstein until 1921 to win a Nobel Prize because the Swedish experimentalists who controlled the award judged his work was too abstract and theoretical.)

His deductive method was the beginning of exactly this new type of theoretical practice, one specific to and responsible for theoretical physics. For the first time, theoretical work was reaching ahead of experimental progress in a new mode of knowledge production unique to the object of theoretical physics. To properly constitute a science "is to *produce* the adequate concept of the object by putting to work means of theoretical production applied to a given raw material. This *production* of knowledge in a given science is a *specific practice* which should be called *theoretical practice – a specific practice distinct from other existing practices… and absolutely irreplaceable at its level and in its function.*"[7] While Einstein began with his thought experiments, his theoretical practice matured with his

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[5] Ibid. 15.

[6] Louis Althusser, "*Ideology and Ideological State Apparatuses: Notes Towards an Investigation*" in *Lenin and Philosophy and Other Essays* (New York, Monthly Review Press, 2001), 116

[7] Louis Althusser, "*Theory, theoretical practice and theoretical formation: Ideology and ideological struggle,*" 15

understanding of his object. By the time he was working to generalize his special theory of relativity in 1915, Einstein had fully realized the value of abstract mathematics. Indeed, by this time it was Riemann's work on metric tensors that was driving his understanding of the non-Euclidean geometry of space-time, leading him to successfully formalize general relativity.

Today's theoretical physicists take this unique theoretical practice to an extreme. As a discipline, particle physics aims to predict the existence of new kinds of matter that might exist only in very specific scenarios, such as the universe in the moments after the Big Bang. Because decades might elapse between the theoretical discovery of a particle and experimental observation, the discipline's theoretical apparatus must have the ability to determine the truth of a particular idea independently. The present search for the Higgs Boson at the Large Hadron Collider is a perfect example of how far theory can run ahead of experimental capability today. For Althusser, this is a hallmark of a properly constituted science. A truly scientific "*theoretical practice* is indeed its own criterion, and contains in itself definite protocols to *validate* the quality of its product…. Once [sciences] are truly constituted and developed they have no need for verification from *external* practices to declare the knowledges they produce to be 'true', i.e., to be *knowledges*."[8] Indeed, the LHC is the largest, most complex, most expensive machine in the *history of humanity*. It was built by CERN, an international consortium, solely on faith in the rigor of physicists' theoretical practice.

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[8] Louis Althusser "*From Capital to Marx's Philosophy*" in *Reading Capital*, Trans. Ben Brewster (London: Verso, 1997), 59.

As confounding as particle physics is, string theory is even farther removed from experiment. Scientists searching for a unified field theory of everything have been working on string theory for decades without any hope of experimental verification. String theory probes the fabric of the universe on such small distance scales that theorists estimate that a particle collider would have to be capable of producing energies more than one million billion times as high as the LHC in order to test the theory's predictions.[9] These predictions, which are the results produced by highly abstract mathematical arguments, make such counter-intuitive claims as an eleven-dimensional space-time. Today, there is significant debate within the scientific community about whether string theory can even be considered a scientific theory if it is (currently and for the foreseeable future) untestable. Ultimately, this is not a "scientific" debate about the nature of the universe but a philosophical debate about the acceptable modes of theoretical practice in physics. Clearly, none of this would have been possible in the problematic of classical physics, which was neither capable of posing these kinds of abstract questions in advance of experimental evidence nor able to evaluate a claim without testable claims.

So if it was not his skepticism about the existence of the ether that drove Einstein's thoughts toward special relativity, where did his deductive method begin? Later, he would claim not to be able to completely untangle the precise series of thoughts leading him to special relativity, but it surely started with a thought experiment he had been pondering for years. Einstein had spent a great deal of time

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[9] Brian Greene, *The Elegant Universe* (New York: Vintage, 2003), 141.

thinking about what it would be like to observe a light beam while traveling at the speed of light. He started with what was a long held belief in the principle of relativity, which argued that the laws of physics should be the same for any observer in an inertial reference frame (an observer traveling at a constant speed in the same direction). Galileo had proved this to hold for classical mechanics, but Einstein believed that it should hold for all physical laws, including Maxwell's equations.

This first postulate received its force from Einstein's thinking about a particularly troublesome asymmetry in the classical theory of electrodynamics that came to his attention while helping his father engineer some inductors for an electric generator. (Inductance is the property by which an alternating magnetic field is able to induce a current to flow in a separate coil of wire.) According to classical electrodynamics, there were different equations governing the situation when a magnet was moved past a stationary wire coil and when a wire coil was moved past a stationary magnet. Einstein could not fathom why these two situations should be distinct, since the relevant physical change was the relative motion of the two objects. Even Galilean relativity suggested that there should be no mechanical way to determine which object's inertial reference frame was "at rest." Yet electromagnetic theory *did* have a third term to define the state of absolute rest: the ether, which allegedly transmitted the electromagnetic waves between the magnet and the wire. Without the ether, there would be no need to formally explain the two physically identical scenarios differently.

This asymmetry was the key to Einstein's formal rejection of the ether in his seminal special relativity paper, "On the Electrodynamics of Moving Bodies." Restoring the logical unity to the problem of inductance "suggest[s] that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the ideas of absolute rest…. [Thus] the introduction of a 'light ether' will prove to be superfluous, inasmuch as the view to be developed here will not require a 'space at absolute rest.'"[10] This is the first step of Einstein's break with the problematic of classical physics. Removing the concept of absolute rest – thereby asserting the fundamental relativity of motion – collapses the apparent asymmetry, which had been allowed to persist for so long because it was not strictly "wrong" according to the logic of the old problematic. Indeed, the asymmetry was a symptom of that faulty logic itself.

For Althusser, this symptomatic reading is the exact process necessary to found a new, scientific problematic. In *Reading Capital*, he argues that Marx's achievement was not the ability to see what bourgeois political economy could not – the answer to the question "*what is the value of labor?*" – but the sense to "*explain the non-vision inside its vision*" by articulating the absences within its text.[11] In arguing for the relativity postulate, Einstein accomplished a similar feat, which can be explained by reformulating Althusser: "It is not [Einstein] who says what the classical text does not say, it is not [Einstein] who intervenes to impose from without on the classical text a discourse which reveals its silence – *it is the classical*

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[10] Walter Isaacson, *Einstein*, 127

[11] Louis Althusser "*From Capital to Marx's Philosophy,*" 23

text itself which tells us that it is silent: its silence *in its own words*."[12] He neither posited the identity of the ether as the state of absolute rest nor created the asymmetry in the explanation of inductance. Instead, he was able to show the logical absence in the classical problematic itself – that is how the two inductance scenarios could be physically distinguished. This absence in the classical problematic was the kind of rift with the reality it supposedly represented, and that is indicative of a false problematic. Here, Newtonian physics revealed a fundamental misunderstanding of its own theoretical object.

Einstein's second postulate involved the velocity of light. There were two possible explanations for the propagation of light. If light were composed of particles it would not need an ethereal medium but its velocity would depend on the speed of its source. (Imagine how a bullet shot straight ahead from a fast moving car would get a speed boost, relative to the ground, compared to a bullet shot from a gun at rest relative to the ground.) This possibility was supported by the research into light quanta Einstein had recently completed. Yet if light behaved more like a wave, then it would travel at a constant speed (c = 2.98 x 10^8 $^m/_s$) regardless of the motion of its source or observer. (This is analogous to the behavior of sound, which travels 770 miles per hour in air no matter how fast its source is moving. The motion of the source or the observer merely affects the perceived frequency of the tone; this is known as the Doppler effect). After much effort expended to adapt Maxwell's equations to explain the first possibility (an emission theory of light), Einstein settled on the second option. From this logic he produced the light

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[12] Ibid. 22.

postulate: “Light always propagates in empty space with a definite velocity that is independent of the state of motion of the emitting body” (Isaacson, 120). Overwhelming astronomical evidence – all starlight reaches Earth at the same speed – validated this choice.

However, when Einstein combined these two postulates in his thought experiments they appeared to contradict each other. If a ray of light were sent down a railroad track, it would appear to travel past a stationary observer (someone standing on the ground) at *c*. Yet if another observer were on a train moving at 0.4*c* in the same direction as the light beam, Einstein realized that the light might seem to be traveling at 0.6*c.* According to the relativity postulate, there should be no physical method to determine which observer is “at rest” in any absolute sense since he had already done away with the absolute rest frame of the ether. However, if the observers’ motion was truly indistinguishable then, according to the light postulate, they should both perceive the light to move at *c*. The contradiction initially seemed insoluble.

Einstein’s brilliant resolution to this apparent contradiction completed the primary break with classical mechanics that began with the rejection of the ether. One morning, Einstein realized he had to work out a rigorous operational definition of time to replace the classical notion of an absolute progression of time. In his *Principia*, Newton asserted that “absolute, true, and mathematical time, of itself and from its own nature, flows equably without relation to anything external” (Isaacson, 125). This self-evident statement had, for 216 years, functioned as a stand in for any rigorous formulation of the meaning of time. Einstein reformulated time as a statement about simultaneity, which turned out to depend on an observer's perspective. Returning to the train scenario and adding some inclement weather is sufficient to provide a brief explanation of simultaneity. To say an observer on the ground witnesses two equidistant bolts of lightning strike "simultaneously" is to say that he sees the light from these events arrive at the same time. However, these same events appear differently to the observer on the train. If she passes the stationary observer at the exact moment of the lightning strike, she will have moved a little distance in one direction by the time the bursts of light reach her. Because she will then be closer to the location of one strike than to the other, the two flashes of light will not arrive "simultaneously." Thus, there is an irreconcilable difference between the "time" in these two inertial reference frames. In other words, an observer "at rest" perceives a clock in a rapidly moving inertial reference frame appears to move more slowly. (For a more detailed description of this thought experiment and an explanation of Lorentz contraction, see Isaacson, pp. 122-35 or Greene, 23-53.)

This discrepancy allowed Einstein to confidently abolish the notion of an "audible tick-tock everywhere in the world that can be considered as time."[13] Time dilation implied that the notion of an absolute space should also be abandoned, producing the concept of Lorenz contraction (rapidly moving objects appear shorter to observers "at rest"). Together, these concepts radically destroyed the Newtonian ideas of discrete and absolute space and time. While Newtonian mechanics had demonstrated an incredibly accurate predictive power for generations, special

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[13] Walter Isaacson, *Einstein*, 128

relativity disproved its most fundamental assumptions about the fabric of the universe. In place of absolute three-dimensional space and universal time, Einstein posited an invariant, four-dimensional space-time.

Space-time is unthinkable in a Newtonian regime. That is to say: No amount of experimentation and thinking driven by Newtonian logic could have arrived at the concept of space-time, since absolute space and time are essential terms undergirding the Newtonian equations describing motion. Before special relativity, "space remained… simply the passive container of all events."[14] Again, the problem was not one of classical physics' vision but the absolute epistemological limits of the classical problematic. In order to think the ideas of special relativity, Einstein had to do more than new calculations; he had to reformulate the very terms on which his discipline understood its theoretical object. In a letter to a close friend, Einstein displayed his clear understanding of this epistemological necessity: "After efforts to discover the privileged state of movement of this hypothetical ether through experiments had failed, it seemed that *the problem should be restated*. That is what the theory of relativity did. It assumed that there are no privileged physical states of movement and asked what consequences could be drawn from this."[15] In restating the problem and posing the question "what is time?" Einstein "produce[d] the as yet unposed question, which the as yet un-asked-for answer answered."[16] This, Althusser argues, is the exact process by which a new problematic is constituted.

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[14] Albert Einstein, "*The Problem of Space, Ether, and the Field in Physics*" (1934) in *Ideas and Opinions*. (New York: Bonanza.) 280
[15] Walter Isaacson, *Einstein*, 131. Emphasis mine
[16] Louis Althusser "*From Capital to Marx's Philosophy*" in *Reading Capital*, Trans. Ben Brewster (London: Verso, 1997), 23

From the perspective of this new problematic it is finally possible to understand the true theoretical status of the ether, which no longer appears to simply be an incorrect answer. Retrospectively reading the terrain of the Newtonian problematic, it is now easy to see how "physical space and the ether are only different terms for the same thing…. [But] if no particular state of motion can be ascribed to the ether, there does not seem to be any ground for introducing it as an entity of a special sort alongside of space."[17] The theoretical appearance of the ether is an effect of the Newtonian problematic itself, which required some way to bridge the gap in logic between Maxwell's wave equations (these mathematically derived equations now appear as premature elements anticipating the modern problematic) and the solely mechanical effectivity of Newtonian dynamics. It is the Newtonian answer to the question unasked in classical problematic: "What is space?"

In epistemological terms, the ether is a manifestation of the ideology required by the old problematic. Adapting Althusser's formulation to the knowledges of theoretical physics it is possible to understand how "ideology must be thought of as sliding into all the parts of the edifice, and considered as a distinctive kind of *cement* that assures the adjustment and cohesion of [elements] in their roles, their functions, and their [physical] relations."[18] This *cement* fills in the problematic's structural fissures, sutures together incorrectly formulated theoretical objects, and ensures these elements' proper functioning according to the logic of the given problematic. This is why, in order to reject the existence of the

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[17] Albert Einstein, "*The Problem of Space, Ether, and the Field in Physics*," 281

[18] Louis Althusser, "*Theory, theoretical practice and theoretical formation: Ideology and ideological struggle,* 25

ether, he needed to effect a wholesale break with a structure that not only harbored these specific ideological concepts but was a *fundamentally ideological problematic*: "a total *system* of [ideological] representations, a system that is, in principle, orientated and distorted, a system dominated by a *false conception* of the world [and] of the domain of objects under consideration."[19] This is why, before he could explain time dilation or Lorenz contraction, Einstein was compelled to refound his discipline in a properly scientific problematic.

Quantum Mechanics: Fundamental Uncertainty

In May 1905, before publishing the first paper of his miracle year, Einstein corresponded with a close friend about four papers he was working on. "The first," he wrote, "deals with radiation and the energy properties of light and is very revolutionary."[20] He was right. The paper, "On a Heuristic Point of View Concerning the Production and Transformation of Light," built on Max Planck's recent work on blackbody radiation and completely upended the classical theory of the nature of light. The success of Maxwell's equations had thoroughly convinced physicists that light, like all electromagnetic radiation, is a wave. However, Einstein argued in his paper that a wave theory of light did not tell the whole story; there were aspects of light's behavior that indicated it could be described in concert as composed of discrete packets of energy.

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[19] Ibid. 24.

[20] Walter Isaacson, *Einstein*, 93

In 1900 Planck had been studying the spectra of blackbody radiation, a problem that had thus far eluded inductive explanation. His attempts to produce a mathematical model of the spectra were unsuccessful until he reluctantly applied Ludwig Boltzmann's statistical methods, which he had previously resisted. Strangely, he could only get the model to work if he included an unexpected tiny constant: $h = 6.62607 \times 10^{-34}$ joule-seconds. Planck explained this unexpected parameter, today called "Planck's Constant," as an artifact of his calculation that models how matter absorbs and emits energy. While he realized h was the most important aspect of his research, he refused to believe it was an intrinsic characteristic of energy. He imagined that molecules of matter acted like tiny harmonic oscillators, which are only able to absorb energy in specific, discrete quantities. He assumed the molecules of matter could only absorb electromagnetic energy in multiples of some miniscule quantity. In this view, quantization was merely an effect of matter absorbing and emitting energy, not a characteristic of the energy itself.

Einstein started with Planck's result but assumed h to have more physical significance; he imagined that light *really is* composed of discrete points of energy. He called these localized particles "quanta," the smallest possible units of energy. The truly revolutionary aspect of the theory, however, was that Einstein did not completely discard the classical wave theory of light, best described by Maxwell. Instead, he argued that light could not be fully described by either theoretical formulation. The idea of an emission theory of light was not new – even Newton held this belief – it was Einstein's ability to think this intrinsic duality that upset the categories physicists had relied upon for generations.

After Einstein's paper was published, it took years for the scientific community to understand and accept the intrinsic wave/particle duality of light. Most astonishingly, Planck himself resisted the concept for quite some time since it undermined his strictly classical understanding of the physical world. Philosophically, asserting this duality restored the proper relation between the knowledge and its proper object. Physicists' initial ideological misgivings about quantum mechanics were founded on an incorrect, empiricist epistemology that confused the true object of knowledge, preventing scientific progress. In an empiricist problematic, knowledge "is completely *inscribed in the structure of the real object*, in the form of the difference between the inessential and the essential…. Knowledge is therefore already *really* present in the real object it has to know."[21] In this model of knowledge production, controlled experiments are designed to strip away the dross of the inessential to expose and probe the kernel of truth, i.e., its knowledge. Thus, according to this empiricism, the categories produced in knowledge are *really existing* categories in the real object itself. In terms of the problem of light, this was the mistake of classical physicists: to attribute the absolute categories of wave and particle dynamics (categories that are productions in knowledge) to the real object itself (light). In other words, physicists ascribed the same absolute difference between and radical nonidentity of waves and particles to the *real* phenomenon of light propagation that existed in their system of knowledge.

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[21] Louis Althusser "*From Capital to Marx's Philosophy,"* 38

Once again, Einstein was able to refound his discipline on an appropriately scientific footing, this time by practically asserting the proper relation between knowledge and its object. Maintaining scientificity requires awareness of "the *distinction* between the *real object*… and the *object of knowledge*, a product of the thought which produces it in itself… as a *thought-object*, absolutely distinct from the real-object."[22] Thus, the real object – light propagation – is abstracted to produce a theoretical object, which is the one studied by physicists. Einstein recognized this epistemologically necessary difference by realizing (at least in a practical manner) how "the production process of the object of knowledge takes place entirely in knowledge and is carried out according to *a different order*, in which the thought categories which 'reproduce' the real categories do *not* occupy *the same* place as they do in the order of real historical genesis, but quite different places assigned them by their function in the production process of the object of knowledge."[23] The empiricist error of the conservative physicists can therefore be read as a calcification and disavowal of this process. Because their discipline was not sufficiently theorized, because classical physics never interrogated its problematic, this process of knowledge production was forgotten and they began to confuse the wave/particle categories – constructed as a processual element of the production of physical knowledge – with the natural characteristics of the real object itself. They forgot that their categories were produced to rationalize, divide, and make meaning out of Nature. They forgot that Nature didn't follow the laws set out by men.

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[22] Ibid. 41.

[23] Ibid.

After Einstein was able to convince the physics establishment to soften the logic of their mutually exclusive categories work on quantum mechanics exploded. The pace of innovation increased so rapidly that Einstein himself went from being an iconoclastic insurgent to a figure of conservative authority. As Einstein aged, younger physicists – Bohr, Born, de Broglie, Schrödinger, Pauli, Dirac, and Heisenberg – took the lead in probing the profoundly weird characteristics of the universe at this small scale. Increasingly, Einstein not only found himself following the work of these others but also refused any theoretical advance that undermined his foundational belief in the strict determinism of the universe. In a particularly apt quip, Einstein remarked, “To punish me for my contempt of authority, Fate has made me an authority myself.”[24]

Just as Planck had resisted Einstein’s radical leap from his blackbody results, Einstein became a powerful voice against the work of the Niels Bohr and his Copenhagen school. The theoretical work of Werner Heisenberg disturbed Einstein most profoundly. In 1927, Heisenberg formulated his (in)famous uncertainty principle, which stated that it is impossible to simultaneously know both the exact position and exact momentum of a particle at any given time. Combined with Erwin Schrödinger’s statistical approach to determining a particle’s location with wave functions, quantum mechanics inserted a fundamental uncertainty into the physical knowledge of the universe. The implications of Heisenberg’s Uncertainty Principle (and the others that followed) were both numerous and profound. Experimentation could no longer be treated as a transparent experience of the really existing reality

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[24] Walter Isaacson, *Einstein,* 317

of the universe since the very act of measurement caused a collapse of the wave function and “changed” the result. There was no longer a concept of emptiness, since even a vacuum was proven to have a predictable zero-point energy. It was no longer possible to unequivocally locate a particle with an accuracy that depended only on the sensitivity of the measuring apparatus. Instead of speaking about individual particles, physicists were reduced to making statistical and probabilistic statements about a population of particles. (Each of these quantum mechanical results has an interesting schematic relationship with Althusserian thought, particularly his later writing on the materialism of the encounter. However, these fascinating issues are beyond the scope of this essay.) But the loss of strictly deterministic causality was the development that most disturbed Einstein, who used a lecture on the 200th anniversary of Newton’s birth to publicly declare his hope: “May the spirit of Newton’s method give us the power to restore the union between physical reality and the profoundest characteristic of Newton’s teaching – strict causality.”[25]

Beyond the intransience of his belief in a God who wouldn’t “play dice” with the universe, Einstein’s reactionary stance vis-à-vis fundamental quantum indeterminacy reflects a misunderstanding of the epistemological changes to physics he initiated. Bohr summed up the change: “It is wrong to think that the task of physics is to find out how nature *is*. Physics concerns what we can *say* about nature.”[26] Bohr, along with Heisenberg (“I believe that indeterminism, that is, the nonvalidity of rigorous causality, is necessary.”[27]) and others, understood the need

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[25] Ibid. 333.
[26] Ibid.
[27] Ibid. 332.

for philosophy to keep pace with a changing science. And this change is part of the nature of science itself; Althusser argues, "*The idea we have of science is decisive for… science itself*. If we have a dogmatic conception we will do nothing to develop it, we will indefinitely repeat its results, and not only will the science not progress, it will wither."[28] It is a sad fact that Einstein was not able to place as much face in his own radical theoretical practice as his followers. However, this may be a correlative result of how perfectly his mind was matched to the conjuncture of his miracle year. Indeed, it is almost fitting for the later life of a man, whose unrivaled intuitive grasp of scientific epistemology revolutionized human knowledge of the universe, to serve as a warning against the danger every science faces: science "is constantly submitted to the onslaught of existing ideologies, and particularly to that most disarming – because apparently non-ideological – ideology wherein the scientist 'spontaneously' reflects his/her own practice: 'empiricist' or 'positivist' ideology."[29] Perhaps this danger is exactly why a particular encounter is always finite: because the players are always specific to that particular conjuncture. What it takes to make one encounter "take hold" is specific and non-transferrable to the next.

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This paper represents an initial attempt to bring two highly theoretical discursive fields into contact and closes with more dangling questions than finished answers. Hopefully, future work on the epistemological problems of classical physics and ongoing scientific inquiry of its modern offspring will produce more

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[28] Louis Althusser, "*Theory, theoretical practice and theoretical formation: Ideology and ideological struggle,*" 14.
[29] Ibid. 12.

satisfying connections between the Althusserian philosophy and the content and form of theoretical physics. From allusion to physical processes to invocations of Newton, Althusser's writing calls out for this kind of project. Quantum mechanics and relativity – specifically general relativity, which was largely ignored by this paper since Einstein developed it many years after his primary break with classical mechanics – present unique challenges to a Marxist philosophy of science, which also works to produce knowledges of the most fundamental aspects of the world.

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