Space and Time

Term Paper

Walk up to any physicist and ask if there's such a thing as the luminiferous aether. The response will be universally in the negative. This was the great conceptual leap made by Einstein; rather than positing an aether like that of Poincaré and Lorentz (and Fitzgerald and Larmor) which had an undetectable rest frame due to strange space- and time-warping effects on any object moving through it, he simply eliminated the aether entirely. Despite there being no possible way to observationally distinguish between the so-called "compensatory" aether theory and special relativity as formulated by Einstein, there is a firm consensus among physicists that the latter is the correct theory. There is no place for a universal light-propagating aether in modern theoretical physics, and not a single benighted graduate student in a forgotten corner of some derelict lab is trying to understand the exact workings of the physical mechanism by which the aether compresses objects along their axes of motion. It seems reasonable, therefore, to ask: is this position, so widely held by physicists, philosophically defensible? Is there a way of formulating and defending the claim that Einstein's relativity is actually right, or at least more right than its compensatory predecessors and other empirically equivalent alternatives? I will outline one possible way to do this, provide several counterarguments, and see how someone subscribing to this position might respond and what problems remain.

A scientific realist could defend this position as follows. Einstein's insight was that the aether was unnecessary. He found that starting from the constancy of the speed of light and the principle of relativity, it was possible to derive all the dynamical effects of the compensatory theory, which was a fairly ad hoc theory cobbled together by Lorentz, Poincaré, and others. Granted, there are no possible observational differences between the theories, but that doesn't mean that there isn't a way of choosing between them. Which theory you choose really does make a difference even if their observational consequences are the same, because the two theories make different ontological claims about the world. Saying that there is no aether, that the laws of physics are the same in all inertial frames, and that the speed of light is constant in all directions in all such frames is saying something genuinely new and different than the compensatory theories. If the theory of meaning held by reductionists like Reichenbach does not allow for this, so much the worse for that theory. As for the question of choosing between the theories: physicists have found Einstein's formulation to be more parsimonious, elegant, useful, and fecund, and these considerations surely must count for something.

This position has multiple weak points. I will first focus on an argument that is not a general critique of the coherency of scientific realism as a position (the sort of critique that realists have become quite accustomed to), but rather a pointed attack on this particular distinction using the realist's very own much-vaunted evidence of how scientists *actually* work. I've pulled this particular example from a paper by J. S. Bell. Bell lays out an interesting relativistic puzzle, which runs as follows.

Start with two rocket ships, of identical make and model, oriented in the same direction, with some distance L between the tip of the one behind and the tail of the one in front. Tie a string between the two ships that just reaches from one to the other without being stretched—meaning the string has a proper length L when it is under no tension. Once this is done, you radio your friends in the two ships, and they turn on their rockets at the same time as measured in your frame. Since the ships are identical, they accelerate at the same rate, meaning that in your frame, the ships are always moving at the same speed—and therefore the distance between the ships does not change. The string, on the other hand, contracts more and more as it goes faster and faster, thus increasing the tension in the string until, once the speed of the ships-and-string system reaches a certain point, it breaks.

As Bell colorfully notes, nearly all physicists, when confronted with this description, will smell something fishy about it. There is a strong intuition that somehow comes from Einsteinian relativity that says the distance between the ships should be contracted as well, and thus the string does not break. That impression is erroneous—the string does indeed break. To see this, let's look at the situation from the perspective of one of the ships, say the one in front (it doesn't matter which). In that (accelerated) frame, the ship in back starts its engines later than the ship in front, and thus the distance between the two ships increases, eventually snapping the (uncontracted) string. As Bell says, "It is only after working this out, and perhaps only with a residual feeling of unease" (Bell 68) that most physicists will accept that the string actually breaks.

Bell goes on to point out that this same conclusion is quite simple to reach if you work in the mindset of the compensatory theory. When length contraction is seen as a mechanical effect due to the motion of objects through the aether, it's perfectly obvious that the distance between the ships doesn't change, and it's equally obvious that the string feels an increasing tension as it moves faster and faster yet is forced to remain at the same length. Bell uses this example as an argument in favor of teaching the compensatory theory along with Einstein's version of relativity, since he feels that the latter presented alone can "destroy completely the confidence of the student in perfectly sound and useful concepts already acquired" (Bell 67).

Based on Bell's position, another scientific realist might come along and say "Aha! So, sometimes there is cause for scientists to use this empirically equivalent theory, the compensatory theory, in place of Einstein's relativity. Therefore, *even by our own realist lights*, there's no basis for saying that Einstein is 'actually right.' The two formulations are equivalent, much like the Schrödinger and Heisenberg pictures of quantum mechanics."

The first realist has several ways of responding to this. She can start by pointing out that it's far from clear that Bell intended to say Einsteinian relativity was fully equivalent (rather than just empirically equivalent) to the compensatory theory. Bell does say that "the facts of physics do not oblige us to accept one philosophy rather than the other," but he goes on to say that "we need not accept Lorentz's philosophy to accept a Lorentzian pedagogy" and is quick to point out "there is no intention here to make any reservation whatever about the power and precision of Einstein's approach" (Bell 77). Furthermore, there are other cases where an alternative, empirically equivalent interpretation can make the mathematics easier to understand, but it's far from clear that in all of those cases scientists are actually saying that the "non-orthodox" interpretation is equivalent to the "orthodox" one. For example, when dealing with the quantum mechanics of superfluids, there are equations that pop up which seem quite strange when viewed in light of the traditional Copenhagen interpretation of quantum mechanics (an interpretation riddled with very serious problems of its own, but that's a subject for a different paper—or perhaps a twenty-volume encyclopedia). However, these equations, which relate the spatial gradient of the phase of the wavefunction to the velocity of the fluid, are much easier to arrive at and interpret when viewed from the perspective of Bohmian quantum mechanics—an empirically (and mathematically) equivalent theory. It would be a stretch, though, to say that all practitioners of quantum hydrodynamics are by necessity of the opinion that Bohmian mechanics is in fact *wholly* equivalent to the Copenhagen interpretation. (In fact, I'm fairly sure that the opposite is true—while some physicists working with quantum hydrodynamics might think that Bohmian mechanics is the correct interpretation, I'd be surprised if they said that the two interpretations are in fact the *same*.) There are also cases in which scientists describe a theory in a shorthand language, both for convenience and as a sort of analogy, which seems to belong to a theory that is empirically *inequivalent* and flat-out wrong, yet nobody (or at least nobody serious) gets confused. The foremost example I have in mind is that of evolution; many times, when talking about how a structure arose through evolution, biologists will slip into a teleological manner of speaking. We have curved spines in order to better support an upright posture. We have hearts in order to pump blood. These statements seem to imply a final cause for biological systems, but we know that this simply isn't the case. This manner of speaking is a shorthand to facilitate communication, a tacit acknowledgement of the fact that for certain purposes it's just easier to forget about the details of what we know to actually be the case and use simpler language that implies an erroneous worldview, but one which is nonetheless just as good for our purposes. Yet nobody (or again, nobody reasonable) would look at this and say that this means biologists actually think that a teleological theory is equivalent to evolution. Alternative interpretations of theories can sometimes be useful as conceptual "tricks" that help us arrive at the correct answer, or as bookkeeping methods of a sort, but that doesn't mean that they're actually true. (This bears an unfortunate resemblance to the original position of the Catholic Church on the Copernican system—that it was allowable as a computational aid, but that did not in any way change the fact that it was untrue. However, the resemblance does not extend to the intent and the political associations, which is comfort enough for me.)

The realist can also go further and do what Einstein did—employ some *a priori* metatheoretical considerations to dismiss the compensatory theory. The compensatory theory states that there really is an aether and that it really has a rest frame, but that the laws of nature are such that we can never find it. Thus, there is not one compensatory theory—there are an infinite number, one for each possible rest frame of the aether (namely, every possible inertial frame). There is absolutely no compelling reason to choose any of them over any other—all of the compensatory theories are empirically equivalent. Yet, according to the realist, they all say genuinely different things about the state of the universe. Using some sort of *a priori* principle similar to Leibniz's principle of sufficient reason, the realist can make the argument that there is no reason to choose any of the compensatory theories over all the others—but since there is a unique theory with the assumptions made by Einstein (no aether being among them), and since that theory does not posit the existence of something we can never find (the rest frame of the aether), there *is* reason to choose that theory over others.

This kind of reasoning can also be deployed effectively by the realist against other empirically equivalent alternatives to Einstein's theory. For example, a particularly popular set of such theories are the $\varepsilon \neq \frac{1}{2}$ theories. These theories alter Einstein's definition of distant simultaneity and then alter the Lorentz transformations correspondingly to keep the observational consequences of the theory unaltered. Briefly: Einstein outlines a procedure for determining when distant events are simultaneous, and thus a way of synchronizing distant clocks. (The procedure I'm about to describe is not Einstein's original procedure, but instead one that is totally equivalent and that I find somewhat easier to work with.) Place a light source exactly halfway between two points, A and B. Send two beams of light out from the source at the same time, one towards A and one towards B. The event of the latter light beam arriving at B is simultaneous with the event of the former light beam arriving at A. In this scenario, ε is the fraction of the distance from A to B at which the light source is placed. Einstein chose $\varepsilon = \frac{1}{2}$. The claim has been made that this is a conventional choice, as any choice of ε between 0 and 1 can lead to an internally consistent theory that is empirically equivalent to special relativity. (Choosing an ε outside the interval (0, 1) would lead to scenarios in which it would be possible for an object moving at subluminal speeds to do strange things, such as leave B and arrive at A before it left.)

These theories do not present any more of a problem for the realist than the compensatory theories do—if anything, they present less of a problem, because I am unaware of any situation (and I certainly cannot think of one) in which the use of one of the $\varepsilon \neq \frac{1}{2}$ theories would be useful as a conceptual aid. The realist is free to make the same sort of parsimony argument that can be made against the compensatory theories. Choosing $\varepsilon \neq \frac{1}{2}$ is equivalent to saying that the one-way speed of light is not the same in all directions; there's no compelling reason to single out any particular direction over any other, and thus $\varepsilon = \frac{1}{2}$ really is a simpler and therefore more reasonable theory.

What would a logical empiricist like Hans Reichenbach say about this position? The compensatory theory and Einstein's theory are empirically equivalent; therefore he would say that the two theories are not actually different, but have only a "mere descriptive difference." Not only is there no rational basis for choosing between the interpretations, but it is not logically coherent to talk about choosing between the interpretations, because they are not actually different. Empirical equivalence is full equivalence.

The hypothetical realist's response is fairly predictable given her initial statement of her position back in the second paragraph. There are an infinite number of theories that are empirically equivalent to Einstein's formulation of relativity. For example, there's the class of compensatory theories that not only posit an aether, but a *sentient* aether that is (tragically) in principle strictly unable to communicate with us or give any indication of its sentience in any way—and, incidentally, this aether has a deep love and appreciation for Aqua Teen Hunger Force (the lack of communication is one-way). Obviously scientists don't seriously consider *all* empirically equivalent theories to be equivalent or true or even useful. How do they pick which ones they will actually consider? There might be considerations of parsimony or utility involved, but then you're edging dangerously close to a realist position. A logical empiricist might be tempted to respond by saying that which empirically equivalent theories the scientists think about doesn't matter. That's not going to fly either, because which empirically equivalent theory the scientific community chooses ends up making a difference (among other places) later on in the progress of the field. Say that new data arises that forces the scientific community to find a new theory. When faced with the fact that finite data can't specify among an infinity of empirically *inequivalent* theories, scientists make judgment calls that are in part based on non-observable entities in their favored interpretation of their current theories. In other words, if you look at the way that science is actually done, you will see that the methods of science are dependent on the non-empirical ontological commitments of scientific theories. Logical empiricism can't account for this.

This response showcases the most serious problems faced by logical empiricism, but it also brings out what might be the gravest problem that our realist has to face. While it does seem to be true that the methods of science depend on the non-observational entities that are posited by scientific theories, the exact nature of the dependence is far from clear. Parsimony seems to play a role in theory selection, but what do we mean by parsimony? What metric do we use for simplicity? Where does that metric come from? How do we apply it? Is it the same in all situations? Similarly, continuity with previous scientific theories has some kind of bearing on the selection of new theories, but it faces many of the same problems, as do other considerations such as the fecundity, utility, and elegance of new theories. And there have definitely been “revolutions” in the history of science where it would be a stretch to say that the theory that was ultimately settled upon was the most parsimonious of all the available options, or the one that preserved the most continuity with previous theories (or the most fecund, or the most elegant, et cetera). It would be difficult, to say the least, to come up with a truly comprehensive account of what non-observational considerations are taken into account in the workings of science. To the best of my knowledge, no efforts to date have garnered anything like a consensus, and such efforts are in any case far beyond the scope of this paper. As Arthur Fine says, “the problem for the realist is how to explain the *occasional success* of a strategy that *usually fails*” (265, emphasis his). In order to hold the position that Einstein’s theory is *the* correct one, this problem must be handled very carefully.

Works Cited

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