Did Einstein Really Believe that Principle Theories are Explanatorily Powerless?

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Did Einstein Really Believe that Principle Theories are Explanatorily Powerless?

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Einstein is widely understood as regarding "principle theories" (such as the theory of relativity) as explanatorily powerless. This brief paper shows that Einstein's remarks admit of another interpretation, according to which principle theories possess explanatory power. This interpretation is motivated primarily by showing that James Jeans made remarks very similar to Einstein's at nearly the same time, but Jeans reconciled those remarks with holding principle theories to be explanatory. Einstein's remarks could well be getting at the same point as Jeans's. This view of principle and constructive theories is independently valuable. It undermines Salmon's "friendly physicist" example as an argument for the view that there are facts that can be explained by both principle and constructive theories.

1. Introduction

In a notable article entitled "What is the Theory of Relativity?" written at the request of *The Times* (London) and published in its November 28, 1919 edition, Albert Einstein famously distinguished "theories of principle" from "constructive theories." Einstein placed relativity theory among the principle theories. His distinction has recently received increased attention, especially as it relates to scientific explanation.

In particular, there has been considerable discussion of how to explain why there obtain the Lorentz transformations (along with their consequences, such as length contraction and time dilation) as well as of how to account for the Lorentz covariance of the dynamical laws. Some philosophers such as Hughes (1989, pp. 198–99), Janssen (2002, 2008), Balashov and Janssen (2003), and Lange (2013) have argued that the facts to be explained transcend the various particular forces holding measuring rods and clocks together. Therefore, the Lorentz transformations and the

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Lorentz covariance of all dynamical laws are explained from the top down: by general principles (such as the principle of relativity) by which all constructive theories are constrained. On this view, principle theories have explanatory power. In contrast, other philosophers—such as Brown (2005), Brown and Pooley (2001, 2006), and Mermin (2005, p. 180)—have emphasized that Einstein adopted the strategy by which he ultimately derived special relativity (of working from general principles, such as the principle of relativity) only because he knew that he had no adequate theory of the dynamical laws governing the fundamental constituents of macroscopic bodies, such as rods and clocks. These philosophers argue that the Lorentz transformations and the Lorentz covariance of all dynamical laws are explained only from the bottom up: by a constructive theory giving the fundamental dynamical laws, whatever they turn out to be.

Advocates of this latter, dynamical view have taken themselves to be following Einstein in holding that theories of principle are explanatorily powerless:

> Einstein's view (one that we share) was that principle theories were 'inferior' specifically in their explanatory power. [. . .] principle theories fail to be explanatory. (Brown and Pooley 2006, pp. 75–76)

> [I]n his 1919 Times article, Einstein was quite explicit both that special relativity is a principle theory, and that principle theories lose out to constructive theories in terms of explanatory power. (Brown and Pooley 2001, p. 261)

Even philosophers who do not endorse the dynamical view of the Lorentz transformations' explanation generally interpret Einstein as denying the explanatory power of principle theories. For instance, Stachel describes Einstein's view of principle theories as follows:

> The principles of such a theory, of which thermodynamics is his prime example, are universal assertions based upon a large amount of empirical data; they do not purport to constitute explanations of the phenomena on which they are based. In contrast, constructive theories, such as the kinetic theory of gases, do attempt to explain some class of phenomena, such as the gas laws on the basis of hypothetical entities employed to construct the explanation, such as atoms in motion. (Stachel 2000, p. 10)

Howard likewise depicts Einstein as holding that only constructive theories explain:

> The 'principles' that make up a principle theory like special relativity or macroscopic thermodynamics are empirically well-grounded

> generalizations that serve a heuristic role by constraining the search for the deeper constructive theories that provide ultimate explanations of phenomena in terms of models constructed from an ontology of systems, states, and interactions. (Howard 2010, p. 349)

It is unsurprising that Einstein is commonly interpreted as holding that principle theories are explanatorily impotent. There seems to be ample textual support. Here is the key, oft-quoted passage:

> We can distinguish various kinds of theories in physics. Most of them are constructive. They attempt to build up a picture of the more complex phenomena out of the materials of a relatively simple formal scheme from which they start out. Thus the kinetic theory of gases seeks to reduce mechanical, thermal, and diffusional processes to movements of molecules—i.e., to build them up out of the hypothesis of molecular motion. When we say that we have succeeded in understanding a group of natural processes, we invariably mean that a constructive theory has been found which covers the processes in question.
>
> Along with this most important class of theories there exists a second, which I will call "principle-theories." These employ the analytic, not the synthetic, method. The elements which form their basis and starting-point are not hypothetically constructed but empirically discovered ones, general characteristics of natural processes, principles that give rise to mathematically formulated criteria which the separate processes or the theoretical representations of them have to satisfy. Thus the science of thermodynamics seeks by analytical means to deduce necessary conditions, which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible.
>
> The advantages of the constructive theory are completeness, adaptability, and clearness, those of the principle theory are logical perfection and security of the foundations.
>
> The theory of relativity belongs to the latter class. (Einstein [1919] 1954, p. 228)

In view of this apparently smoking-gun remark ("When we say that we have succeeded in understanding a group of natural processes, we invariably mean that a constructive theory has been found which covers the processes in question"), it is no wonder that Einstein is commonly thought to have been "unequivocal in his dismissal of the explanatory potential of principle theories" (Frisch 2005, p. 668).

Nevertheless, it remains difficult to believe that Einstein really believed that principle theories are devoid of explanatory power. After all, Einstein emphasized that principle theories consist of law-like generalizations that unify a host of facts. Unification under law-like generalization has often been thought to be intimately bound up with explanatory power. Furthermore, outside of his 1919 article but in connection with the concept of principle theories, Einstein made remarks suggesting that he regarded relativity theory as possessing explanatory power. For instance, in "Physics and Reality" written in 1936, Einstein characterized "the fundamental hypotheses of the theory of relativity" as like "the hypothesis of the non-existence of perpetual motion" in that each is "raise[d] to the rank of a principle," but he then said that the principles of relativity theory have the power "to account" for certain facts—that is, to explain why they obtain:

> In order to account, also, for the equivalence of all inertial systems with regard to all the phenomena of nature, it is necessary to postulate invariance of all systems of physical equations which express general laws with respect to Lorentz transformations (Einstein [1936] 1954, p. 308)

Likewise, in his 1940 essay "The Fundaments of Theoretical Physics," Einstein identified an explanatory gap in classical physics that general relativity fills:

> The general theory of relativity owes its origin to the attempt to explain a fact known since Galileo's and Newton's time but hitherto eluding all theoretical interpretation: the inertia and the weight of a body, in themselves two entirely distinct things, are measured by one and the same constant, the mass. ([1940] 1954, p. 330)

Evidently, Einstein regarded general relativity as explaining a fact that classical physics cannot explain.

Yet there remains Einstein's apparently smoking-gun remark: "When we say that we have succeeded in understanding a group of natural processes, we invariably mean that a constructive theory has been found which covers the processes in question." This passage seems impossible to reconcile with any grant of explanatory power to principle theories. I know of no instance where an alternative interpretation of this passage has even been proposed. My aim in this paper is to propose one.

Admittedly, I have no substantial direct evidence from Einstein's own remarks to offer in support of my novel interpretation. Apart from passages like those I just quoted where Einstein seemed to recognize relativity as having explanatory power (despite being a principle theory), I can supply no additional Einstein sources that my interpretation of the smoking-gun remark makes better sense of than the standard interpretation does. However, as I mentioned, no alternative interpretation of that passage has ever (to my knowledge) been proposed, even as a possibility. So although the evidence that my interpretation captures Einstein's meaning remains far from conclusive, I believe that this paper would make a useful contribution even if it showed merely that the smoking-gun passage reasonably admits of another interpretation besides the standard one.

Moreover, I do have some circumstantial evidence for my interpretation. Consider the following remark comparing relativity to the first and second laws of thermodynamics, which are among Einstein's examples (in his 1919 article) of the "empirically discovered . . . general characteristics of natural processes" that principle theories describe:

> The three principles have in common that they do not explain how or why events happen; they merely limit the types of events which can happen.

This passage sounds very much like Einstein's remarks in his 1919 essay. (Recall he says there that principle theories "give rise to mathematically formulated criteria which the separate processes or the theoretical representations of them have to satisfy.") Indeed, the passage I have just quoted was published early in 1920 (and was delivered at a meeting barely two months after the publication of Einstein's *Times* article), and its author goes on to describe relativity theory as not "constructive." However, it turns out that the passage's author does *not* take relativity theory to be explanatorily impotent. Rather, he goes on to make clear in what way relativity theory possesses explanatory power. He says enough for us to see how his remark that relativity "do[es] not explain how or why events happen" is supposed to be reconciled with his view that relativity is explanatory.

The passage's author is not Einstein; it is James Jeans. But the passage shows that at the same time as Einstein wrote "What is the Theory of Relativity?," one of Einstein's most visible contemporaries was offering a view of relativity that is naturally expressed (and was actually expressed) in terms of remarks very much like Einstein's smoking-gun passage, and yet this contemporary nevertheless plainly regarded relativity theory as possessing considerable explanatory power. I have no direct evidence that Jeans was (or took himself to be) following Einstein's conception of relativity theory. But I will do more than show merely that there is room in principle for an alternative interpretation of Einstein's smoking-gun passage. I will show (in section 2) that at least one of Einstein's important contemporaries made remarks very much like the smoking-gun passage but that clearly were not intended to characterize relativity as explanatorily powerless. So contrary to the received view, the smoking-gun passage fails to constitute conclusive evidence that Einstein regarded principle theories as devoid of explanatory power.

Putting aside questions about the proper interpretation of Einstein's conception of principle and constructive theories, I will argue that Jeans's view (albeit overlooked in recent philosophical discussions of principle versus constructive theories) makes an important contribution to our understanding of the role that principle and constructive theories play in scientific explanation. It suggests that when we set out to explain a case of length contraction or time dilation, we must distinguish between two possible facts as the explanatory target. On Jeans's view, one of these facts can be explained only by constructive theories—but the other can be explained by theories of principle (and perhaps can be explained only by them).

If we bear in mind the distinction between these two explananda, then we gain a revealing new perspective on previous philosophical discussions of the contrast between principle and constructive theories. For instance, I shall argue (in section 3) that the distinction between these two explananda allows us to properly evaluate Salmon's (1989, pp. 182–85) argument involving his famous example of the friendly physicist. There Salmon purports to show that the same phenomenon can receive both a top down explanation (from general relativity's principle of equivalence) and a bottom up explanation (from Einstein's exemplar of a constructive theory: the kinetic-molecular theory of gases). That is (in Einstein's terminology), Salmon argues that the very same fact can be explained by both a principle theory and a constructive theory, and so both principle theories and constructive theories have explanatory power. However, I shall argue, the distinction that Jeans draws between two explananda allows us to see that in Salmon's example, the principle and constructive theories are actually taking distinct facts as their explanatory targets. Salmon's example therefore fails to show that there are facts that can be explained by both principle and constructive theories.

In distinguishing between two possible explananda, we can recognize a new way of reading Einstein's oft-quoted remarks concerning the explanatory significance of principle and constructive theories. Although the evidence is insufficient to establish that this interpretation captures Einstein's intended meaning, it is sufficient to show that the apparently smoking-gun passage cannot be regarded in the usual manner: as explicit, conclusive evidence that Einstein took relativity and other principle theories as destitute of explanatory power. My interpretation does justice to Einstein's other remarks that apparently recognize principle theories as explanatory. My interpretation identifies an explanatory role that constructive theories alone are fitted to perform, and yet also identifies certain facts as able to be explained by principle theories.

2. Two Distinct Explananda

Let's now look at the context of Jeans's remark quoted above. Like Einstein, Jeans appears at first glance to have contended that relativity, as a theory of principle rather than a constructive theory, is explanatorily impotent. In this regard, he said that the principle of relativity is like energy conservation and the second law of thermodynamics:

> The three principles have in common that they do not explain how or why events happen; they merely limit the types of events which can happen. Thus the principle of the Conservation of Energy shows that water cannot flow uphill; the Second Law of Thermodynamics shows that heat cannot flow from a cold body to a hot; the principle of Relativity shows that a planet cannot describe a perfect ellipse about the sun as focus. But it would be as unreasonable to expect the principle of Relativity to explain why a planet describes an orbit or how a ray of light is propagated as it would be to propound the same questions to the principle of Conservation of Energy or the Second Law of Thermodynamics. All three principles deal with events, and not with the mechanism of events [. . .].
>
> New and mysterious continents appear for science to explore, but it is not for the theory of Relativity to explore them. The methods of that theory are destructive rather than constructive, and, when the theory predicts a positive result, it is invariably for the same reason, namely, that a process of exhaustion shows that any other result would be impossible. (Jeans 1920, p. 66)

Notice Jeans's emphasis on the non-constructive character of relativity, its similarity to thermodynamics, and its failure to provide information about any underlying mechanism or dynamics. In all of these respects, Jeans sounded very much like Einstein about two months earlier in *The Times.*

Nevertheless, Jeans made clear that he believed relativity theory to be explanatorily powerful. Regarding the Lorentz transformations, he said, "These equations explain and predict a great number of physical phenomena,—e.g., the variation of mass with velocity . . ." (Jeans 1920, p. 67). Likewise, he wrote elsewhere that relativity "at once explained the negative results of the Michelson-Morley and of all similar experiments." (Jeans 1951, p. 294)[1]

How can Jeans's various claims be reconciled? The key to understanding his view (and perhaps Einstein's, too) lies in remarks like this:

> Thus the hypothesis of relativity predicts that a freely moving planet cannot describe a perfect ellipse around the sun as focus. This prediction is made on quite general grounds, just as the conservation of energy predicts that a stream of water cannot flow uphill. But the conservation of energy by itself is powerless to predict what will be the actual course of a stream of water, and in precisely the same way the hypothesis of relativity alone is powerless to predict what will be the orbit of a planet. Before this or any other positive gravitational predictions can be made, additional hypotheses must be introduced. (Jeans 1921, p. 793)

These "additional hypotheses" are constructive theories. Jeans's point is that although the principle of relativity and other constraints supplied by relativity impose certain limitations on the kinds of phenomena that could occur, these constraints alone are not enough to entail the details of particular events over and above the fact that they fall within the broad range allowed by the constraints. Rather, the particular outcomes are entailed (or, at least, probabilified) by initial conditions and the dynamical laws supplied by constructive theories. The principle of relativity and its fellow constraints do not form a complete theory, and they cannot explain what they do not entail (or probabilify). They must be supplemented by constructive theories. But they can nevertheless "explain and predict a great number of physical phenomena," namely, those that they do suffice to entail.[2]

For instance, consider a bar of a certain length moving uniformly in a given inertial frame S. What accounts for the bar's length in S? Only a constructive theory giving the bar's internal constitution and the intermolecular forces within the bar can explain its length. Admittedly, that the bar has a certain length in another inertial frame S′ where the bar is at rest, together with the Lorentz transformations (and the speed in one frame of the other frame's origin), *entails* the bar's length in S. But these facts do not *explain* its length in S. Otherwise the explanations would run

1. As Frisch (2005) points out, Lorentz also drew a distinction similar to Einstein's distinction between principle and constructive theories. Perhaps it was then a fairly common distinction to draw. Lorentz explicitly deemed principle theories to be capable of explaining, perhaps supporting my interpretation of Einstein as also having taken this view.

2. For more on what a constraint is and how a constraint's modal status gives it explanatory power, see (Lange 2011, 2012, 2013).

in a circle, since its length in S together with the Lorentz transformations would by the same token explain its length in S′. There is no reason to privilege one of these frames as explanatorily prior to the other.

However, suppose we aim to explain not the bar's length in S or its length in S′, but rather the *relation* between these two lengths. The Lorentz transformations explain that relation (on Jeans's view) and thus explain length contraction. This is not an explanation that works by describing a causal mechanism; relativity does not specify any causal mechanisms. That is why it cannot predict the bar's actual length, just as the conservation of energy "is powerless to predict what will be the actual course of a stream of water." But just as conservation of energy as a constraint does help to explain why a stream of water does not flow uphill (because its doing so is impossible), so the principle of relativity as a constraint helps to explain why the bar's lengths in the two frames stand in a certain relation (because any other relation would "be impossible," as Jeans says).

Suppose that the bar, having a certain length and moving uniformly in S, is accelerated to a new speed and then brought into uniform motion at that new speed in S. Once again, the principle of relativity together with other constraints supplied by relativity theory do not suffice to entail (or to explain) the relation between the bar's new length in S and its former length in S. The process of acceleration could have changed the bar's internal constitution in a host of ways that only a constructive theory could explain. No theory of principle suffices to entail (or to assign some chance to) whether its internal constitution remains the same in various respects despite its having undergone acceleration. In contrast, the *relation* between the post-acceleration bar's length in S and its length in another inertial frame S′ is again entailed and (on Jeans's view) explained by the principle of relativity together with other relativistic constraints. Consistent with his remarks, Jeans could even have held that the relation between the post-acceleration bar's length in S and its length in another inertial frame S′ has no causal, constructive explanation at all, but *solely* an explanation supplied by the constraints in the theory of relativity—a principle theory.

The same distinction between explananda can be drawn in other examples that have been introduced in order to argue that only constructive theories explain. For instance, Bell (1987, 67) considers two rockets connected by a rope and accelerating equally. Although the rockets' separation remains constant as the rockets speed up, the rope undergoes Lorentz contraction. Hence, it tightens and may eventually break when a sufficiently high speed is attained. Jeans's remarks suggest that he would agree that only a constructive theory of the intermolecular forces within the rope can explain the point during the process of acceleration at which the rope breaks. Only a constructive theory entails (and thereby explains) how much acceleration the rope can withstand without being torn apart. In each frame in which the sequence of events may be described, there will be some causal explanation of the rope's breaking given by a constructive theory (and the preceding events in that frame). This is a point that advocates of the dynamical view of relativity theory properly emphasize. But if we ask instead why the rope's length in one frame stands in a certain relation to its length in another frame, then (on Jeans's view) the Lorentz transformations as constraints would supply an explanation. Jeans would even be free to insist that this relation has no causal, constructive explanation at all.

The same point applies to a force law more generally. The inventory of force laws explains why there are certain forces in nature rather than certain other, hypothetical forces that we might imagine. The constraints supplied by relativity theory are not enough to entail the particular force laws there are. However, certain *relations* between the force laws governing two distinct interactions (such as that they are alike in both being Lorentz covariant) are not only entailed by the two force laws but also entailed independently by the constraint that all of the force laws must be Lorentz covariant. In view of this constraint, any other relation is impossible, thereby explaining (on Jeans's view) why this relation holds.[3]

These limits on the explanatory power of principle theories, rather than the wholesale explanatory impotence of these theories, was what Jeans was expressing in his remark regarding energy conservation, the second law of thermodynamics, and the principle of relativity—that "[t]he three principles have in common that they do not explain how or why events happen; they merely limit the types of events which can happen." These principles do not explain the details of particular events such as the bar's having a given length in a given frame at a given time. But by imposing limitations on which can happen, these principles explain some facts, such as the relation among the bar's lengths in different frames. Jeans's remark appears to be getting at the very same point as Einstein's smoking-gun remark. But if that is correct, then Einstein's point was merely that we cannot understand a group of natural processes without having a constructive theory covering them; some results of those processes are not entailed

3. Of course, the constraint would not only explain why the force laws governing two distinct interactions are alike in both being Lorentz covariant, but also explain why the law governing a given kind of interaction is Lorentz covariant. (Whatever that law is, it would have to be Lorentz covariant.) Notice also that I am not suggesting that the only facts that relativistic constraints can explain are facts about the relations between quantities in different frames.

by relativistic constraints alone. Accordingly, he includes completeness among the advantages of a constructive theory. But it does not follow from Einstein's remarks that those phenomena that *are* entailed by relativistic constraints alone fail to be explained by them, just as Jeans recognized the explanatory power of principle theories. (Indeed, Einstein's remarks are consistent with the phenomena that are entailed by principle theories having no explanation at all by constructive theories.) That we need to have constructive theories in order to have succeeded in fully understanding a group of natural processes does not entail that no why questions at all about those processes can be answered by principle theories.

Einstein often emphasized the incompleteness of relativity theory:

> The principle of relativity [. . .] is not to be conceived as a "complete system," in fact, not as a system at all, but merely as a heuristic principle. . . . It is only by requiring relations between otherwise seemingly unrelated laws that the theory of relativity provides additional statements.
>
> For example, the theory of the motion of electrons arises in the following way. One postulates the Maxwell equations for vacuum for a system of space-time coordinates. By applying the space-time transformation derived by means of the system of relativity, one finds the transformation equations for the electric and magnetic forces. Using the latter, and applying the space-time transformation once again, one arrives at the law for the acceleration of an electron moving at arbitrary speed from the law for the acceleration of the slowly moving electron (which is assumed or obtained from experience). Thus, we are not dealing here at all with a "system" in which the individual laws are implicitly contained and from which they can be found by deduction alone, but only with a principle that (similar to the second law of the theory of heat) permits the reduction of certain laws to others. (Einstein [1907] 1989, pp. 236–37)

In emphasizing that relativity is not "a system," Einstein was saying that the relation between relativistic postulates (such as the principle of relativity) and various constructive theories (concerning particular types of interactions) is not the relation of axioms to theorems. For example, the constraints supplied by relativity cannot entail (and therefore cannot explain) the law for the acceleration of a slowly moving electron.[4] But they *can* entail the *relation* between that law and the law for the acceleration of

4. By the same token, the laws of thermodynamics (Einstein's paradigm of a theory of principle) cannot entail the molecular constitution of matter (where statistical mechanics is the constructive theory constrained by thermodynamics).

an electron moving at arbitrary speed. If we interpret Einstein as getting at the same point as Jeans, then the relation between these two laws can be explained by relativity theory because relativity has the consequence of "requiring relations between otherwise seemingly unrelated laws."

3. Salmon's "Friendly Physicist"

In addition to making available new options for interpreting Einstein's remarks on the explanatory power of principle theories, the distinction between explaining what happens in a given frame and explaining the relation among distinct frames can also be usefully deployed in thinking about Salmon's influential example of the friendly physicist. Although at one time, Salmon took all scientific explanation to be causal, he later argued that the same fact can have both top-down and bottom-up explanations (1989, pp. 182–85). An explanation taking a bottom-up approach (he said) describes the causal processes, interactions, and (often hidden) mechanisms responsible for particular occurrences or general regularities, as when the kinetic-molecular theory of gases explains Boyle's law. In contrast, an explanation taking a top-down approach subsumes the explanandum under some extremely general principles, thereby unifying it with other facts. In different contexts, one or the other of these kinds of explanation may be appropriate, Salmon concluded. One of his favorite examples of a fact having both top-down and bottom-up explanations is the fact that a helium-filled balloon in the cabin of an airplane moves toward the front of the cabin as the airplane is accelerating for take-off :

> Why did the balloon move toward the front of the cabin? Two explanations can be offered, both of which are correct. First, one can tell a story about the behavior of the molecules that made up the air in the cabin, explaining how the rear wall collided with nearby molecules when it began its forward motion, thus creating a pressure gradient from back to front of the cabin. This pressure gradient imposes an unbalanced force on the back side of the balloon, causing it to move forward with respect to the walls of the cabin. Second, one can cite an extremely general physical principle, Einstein's *principle of equivalence,* according to which an acceleration is physically equivalent to a gravitational field. Since helium-filled balloons tend to rise in the atmosphere in the earth's gravitational field, they will move forward when the airplane accelerates, reacting just as they would if a gravitational field were suddenly placed behind the rear wall. (Salmon 1989, p. 183; cf. Salmon 1998, p. 73)

According to Salmon, these two explanations provide different kinds of understanding of the same fact: "It is my present conviction that both of these explanations are legitimate and each is illuminating in its own way" (Salmon 1989, pp. 183–84; cf. Salmon 1998, pp. 9–10).

Salmon's distinction between causal-mechanical, bottom-up explanations and top-down explanations from general overarching principles appears to be similar in many ways to Einstein's distinction between the roles played by principle theories and constructive theories. (Einstein and Salmon both give the kinetic-molecular theory of gases and relativity theory as exemplifying the two approaches.) However, Salmon himself does not draw this comparison, perhaps because Einstein is widely regarded as contending that only constructive theories explain whereas Salmon's point is that both types of theories do.

However, if we again distinguish between explaining what happens in a given frame and explaining the relation among distinct frames, then we see that Salmon's friendly physicist example fails to show that the same fact can receive both top-down and bottom-up explanations. Let's begin by focusing on explaining what happens in a given frame. According to Salmon, the principle of equivalence together with the behavior of helium-filled balloons in earth's gravitational field explains their behavior in the accelerating airplane. ("Since helium-filled balloons tend to rise in the atmosphere in the earth's gravitational field, they will move forward when the airplane accelerates [. . .].") But I see no reason for the balloon's behavior in the earth's gravitational field to take explanatory priority over the balloon's behavior inside the accelerating airplane. With the principle of equivalence, we could just as well infer what balloons do in the earth's atmosphere from what they do inside the airplane. Neither fact explains the other—just as a bar's length in an inertial frame where it is moving uniformly, together with the Lorentz transformations (and the speed in one frame of the other frame's origin), entails but (we saw earlier) does not explain the bar's length in another inertial frame where it is at rest, since its length in one frame does not take explanatory priority over its length in another. To explain the bar's length in either frame, we would need a constructive theory. The same applies to explaining the balloon's behavior inside the accelerating airplane (or in the earth's gravitational field). This is (on the interpretation I have floated) precisely Einstein's point in his smoking-gun remark regarding the explanatory role of principle theories.

However, Salmon (and Einstein) could still maintain that just as there is a top-down explanation of the *relation* between the bar's lengths in the two frames, so there is also a top-down explanation of the *relation* between what balloons do in the earth's gravitational field and what they do in the accelerating airplane. In view of the principle of equivalence, it is no coincidence that the balloon behaves in the same way in the two cases. Contrary to Salmon, then, we do not have here two explanations of the same fact, one proceeding from the bottom up and the other working from the top down. Rather, we have two explanations of different facts. (Salmon could then still use the example to argue that science supplies both top-down and bottom-up explanations.)

The distinction that I have used in order to interpret Einstein's oft-quoted remarks about principle and constructive theories thus has wide application. Even if Einstein held that there are certain facts that only a constructive theory can explain, we should be cautious in concluding that on Einstein's view, there are no facts that principle theories explain.

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