Munich Center for Mathematical Philosophy (Curiel)
Stanford University (Friedman)
University of California, Irvine (Malament, Weatherall)

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Hempel Award Committee
Philosophy of Science Association

Dear Colleagues,

We write to nominate Prof. Howard Stein (Chicago, emeritus) for the Hempel Award.

Stein received his Ph.D. in Philosophy from the University of Chicago in 1958, under the supervision of Rudolf Carnap. He went on to hold positions at Case Western University, Columbia University, and the University of Chicago, before retiring in 2000. In addition, he was awarded fellowships by the National Science Foundation (twice) and the Guggenheim Memorial Foundation. Over the roughly 40 years in which he produced and published research articles, Stein developed a novel and highly influential approach to the philosophy of physics in particular, and to the philosophy of science in general. Shaped by a deep sensitivity to the history of the problems he wrote on and informed by an intimate knowledge of the technical and formal material of the science itself, Stein's work has demonstrated the importance, to metaphysics and to epistemology, of the development of physics; and the importance to scientific thought of essentially philosophical ideas. He has taught us that metaphysics, physical theory, and scientific method are deeply intertwined—an insight that may today seem commonplace, but which was hardly appreciated by the logic empiricists who preceded Stein, and which could not have been achieved without the historical, philosophical and mathematical sophistication that Stein brought to bear.

It is these contributions that have made Stein, as one of us (Friedman) puts it in a supporting letter, "the leading writer and guiding light in philosophically oriented history of science" over the last fifty years. One cannot overstate the influence his work has had on subsequent generations of philosophers of science and physics.

It is on the basis of the exceptionally high quality and lasting influence of his work that we believe Stein deserves the Hempel Award. In what follows, we will support this judgment by discussing a handful of examples. The supporting letters, by Michael Friedman, George Smith, David Malament, Wilfried Sieg, and Bill Harper, will go into further detail about particular facets of Stein's wide-ranging contributions, from the history of modern philosophy, to the philosophy of mathematics, to technical issues in the foundations of general relativity and quantum theory. Our goal in this nominating letter is to focus on the bigger picture: to step back and illustrate both the breadth and the depth of Stein's work, and to explain how it has shaped the fields to which he has contributed.

We begin with Stein's first published article, "Newtonian Space-Time". This article is (we would argue) the most influential paper on the structure of space and time in pre-relativistic physics, and on the absolute/relational debate in the history of physics, written in the second half of the twentieth century. It was published in 1967, in an obscure volume—an issue of the now-defunct journal *Texas Quarterly*—that contained the proceedings of a conference at the University of Texas on the occasion of the 300th anniversary of Newton's *annus mirabilis*. Despite the fact that the original article is nearly impossible to find (or was, until one of us put a scanned version online), it has been cited over 225 times, and the ideas it contains (very much for the first time) have become such a deep part of contemporary thinking in philosophy of space and time that they are now part of the vernacular, regularly used without citation or reference. (Indeed, in his letter George Smith remarks that this paper alone constitutes strong grounds for Stein's receiving the Hempel Award.)

Like all of Stein's papers, this one has many valuable insights and observations. But its main contribution concerns the role that "absolute space" played in Newton's thought. Stein begins the paper by observing that Newton's laws of motion and of universal gravitation presuppose certain geometrical structure: they require, for instance, well-defined notions of distance between locations in space and duration between events at different times. They also require a notion of (absolute) *acceleration*, which amounts to an assignment of magnitudes to trajectories through space over time. Because of the essential role that acceleration plays in Newton's laws (appearing, for instance, in both the first and second laws of motion), Stein suggests, the structure presupposed by Newton's theory is best understood not in terms of space and time separately, but as a geometry of space and time together—of space-time, or, more specifically, of what we now call "Galilean space-time" (and which Stein called "Newtonian space-time" in his paper).

Understanding Newtonian physics in this way was not entirely unprecedented: the mathematical physicist Hermann Weyl had previously defended a similar position. But Stein's next observation was utterly original and ground-breaking: he argued that Newton believed he needed a different, richer structure to support his theory, that of what we now call "Newtonian space-time". (Stein did not name this structure, but used "Newtonian space-time" to refer to Galilean space-time.) Newtonian space-time differs from Galilean space-time by the addition of a notion of "sameness of place at different times", or in other words, a notion of absolute velocity. The difference between absolute velocity and (merely) absolute acceleration is subtle, and it seems that the distinction was out of reach for Newton and his contemporaries—though Stein argues that the Dutch physicist Christiaan Huygens came closest to grasping it. What was clear to Newton, however, was that acceleration was necessary for his theory, and he believed that "absolute space" was the only way to ground an acceptable notion of acceleration. Far from endorsing "absolutism" for obscure metaphysical or theological reasons—as many 19th and early 20th century commentators accused Newton of doing—Newton's views on absolute space were firmly grounded in a scientific problem, concerning how to precisely define the concepts needed to express the laws of motion he had discovered.

There are several points worth remarking on here. The first is that the idea of understanding classical physics through the lens of "space-time" structure, which Stein introduced to philosophy, has been enormously fruitful, with hundreds of subsequent papers and books adopting this vernacular for discussing space and time. The second point concerns the magnitude of the contribution: Stein took a deep and vexed philosophical problem—one debated by the likes of Leibniz, Kant, and Einstein—and provided a new and startlingly insightful way of understanding it. He, for the first time, put his finger on what Newton's famous "spinning bucket" thought experiment established, and showed how one could accept its morals without committing oneself to absolute space in the form that Leibniz and others found so objectionable.

The final remark concerns what this sort of contribution takes. Perhaps the most striking feature of Stein's work, exemplified by "Newtonian Space-Time", is his ability to appreciate the scientific context in which historical work was done, to recognize the character of the problems and the solutions being offered, and to reconceive philosophical problems as an essential part of the development of scientific theory. Where others saw Newton's claims about absolute space and time through the lens of the Leibniz-Clarke correspondence and the status of Leibniz's principles, Stein saw them as a core part of Newton's scientific project.

We will not describe Stein's other contributions in the same depth, but we remark on several others that could be given similar treatment, and which reflect the great breadth of Stein's work.

For instance, Stein also made substantial technical and conceptual contributions to contemporary science. Take, for example, his 1970 article "On the Paradoxical Time-Structures of Gödel". In 1949, Kurt Gödel, Einstein's friend and colleague at Princeton, famously exhibited a solution to Einstein's equation that allowed for a certain form of time travel, in the form of situations in which a particle (or observer) eventually returns to an event in its own past. Gödel argued that his solution had deep consequences for the reality of physical time. But some physicists (and philosophers), including the Nobel laureate astrophysicist Subrahmanyan Chandrasekar (later Stein's colleague in Chicago), cast doubt on Gödel's interpretation of his solution as allowing one "to travel into the past, or otherwise influence the past". Philosophers such as Adolph Grünbaum and John Earman took these critiques very seriously in their writings on time travel in relativity during the 1960s.

Stein's paper definitively put these questions to rest. He established that Chandrasekar and others' critiques were based on a misunderstanding, and showed, in more detail than Gödel himself had done, that Gödel's conclusions were correct. This, in and of itself, was a significant technical achievement, especially given the context. But Stein's paper also raised a number of questions concerning the sense in which time travel is possible in relativity theory that Gödel spacetime alone could not settle—including the question of whether it would be possible, in any given relativistic spacetime (including, for instance, our own) to bring about conditions such that, in the subsequent evolution of the universe, time travel in Gödel's sense would occur. In other words, Stein proposed a definition of a "time machine" that might be consistent with the laws of physics. The questions that appear in this paper have set the agenda for the subsequent fifty years of research on time travel in physics, with major contributions to the questions Stein asked by John Earman, Chris Wüthrich, Chris Smeenk, and J.B. Manchak continuing to appear even today.

Stein also made deeply influential contributions to our understanding of relativity theory from a more historical and conceptual perspective. Consider, for instance, his article "Some Philosophical Prehistory of General Relativity", which was first presented at a conference at the University of Minnesota in 1974 and later published in a volume of Minnesota Studies in the Philosophy of Science in 1977. This article addresses a number of core issues in philosophy of physics—including a devastating critique of Ernst Mach's reading of Newton, and its influence on Einstein—but perhaps the most striking thing about this article, from the perspective of the subsequent development of the field, is that it was in this paper that Stein first introduced what is now known as "Leibnizian Space-Time". Stein argues that Leibnizian space-time, a pared-down version of Newtonian space-time as discussed above, is inadequate for formulating a physical theory, because any such theory would suffer from a kind of indeterminism. In several follow up papers appearing over the next decade, John Earman built on Stein's remarks in this paper, developing a line of thought that ultimately led to Earman's re-analysis of Einstein's infamous hole argument in his 1986 book *A Primer on Determinism* and a paper published in the same year. In this sense, then, the enormous literature on the meaning of determinism and its connection to space-time structure that began to appear in the late 1980s and the 1990s grew directly out of Stein's work in the 1970s.

Of course, questions concerning absolute and relational space, and the meaning of relativity, have been core topics in philosophy of physics for a long time. But some of Stein's most original contributions in the history and philosophy of physics concern periods and theories that were overlooked by philosophers of science before Stein drew attention to them. For instance, consider Stein's paper "On the Notion of Field in Newton, Maxwell, and Beyond" (1970). Today, our best physical theories, including general relativity and quantum field theory, are considered "field theories", i.e., theories whose basic entities are fields, which are objects extended through space and time that, at least in some cases, carry energy and momentum. But what is a “field”, and where did this concept, now so central to physics, come from? It is this central and under-explored question that Stein first took up in “On the Notion of Field [. . .]”, where he traces the concept back to two different ideas present in Newton’s work: (1) Newton’s conception of “body” as an association, to regions of space, of those properties necessary for the laws of motion, and (2) Newton’s understanding of gravitational force based on the idea of dispositions of bodies to accelerate in particular ways when present in regions of space. To even clearly distinguish these two senses of “field” was a major accomplishment; to argue compellingly that both can be traced back to Newton was a deep and (at the time) startlingly novel insight into the relevant historical episodes that was anachronistic anathema to historians of science of the day, but has today become near-universally accepted orthodoxy.

But then consider his subsequent, related papers on the conceptual history of electromagnetic theory in the period following Maxwell, such as “‘Subtler Forms of Matter’ in the Period Following Maxwell” (1981) and “After the Baltimore Lectures: Some Philosophical Remarks on the Subsequent Development of Physics” (1987). These papers read as largely historical—they trace the development of æther theories in the late 19th century—but their point, in our view, is to reveal something of the deepest philosophical significance. The 19th century scientists whose work Stein describes were engaged in a project to re-imagine what the basic entities composing the physical world might be, first by looking to oscillations and excitations in some new material substance whose properties they could only guess at—the luminiferous æther—and then by abstracting away from the æther, leaving only the excitations themselves behind, as composing a new category of entity. This work, Stein says, “is itself one important example . . . of what I think deserves to be called the discovery of the structure of reality” (Stein 1970, p. 285).

Stein was able to link this new kind of entity to Newton’s two notions of field as described above. But he also shows how the full concept of field in the modern sense has features Newton could not have imagined—and indeed, as Stein says, it “broke the Newtonian abductive scheme for natural philosophy” (ibid p. 284) because the entities and structure (namely, the æther) that appeared necessary to make sense of the laws of nature as Maxwell discovered them turned out to be illusory, and a satisfactory resolution to the puzzled faced by Maxwell and his contemporaries required 40 years of work and Einstein’s fundamental reconception of space and time. And in this development, we see not only the invention of a new category of matter—one that was not available to Newton, Leibniz, or Kant, much less Aristotle—but also a reconsideration of scientific method. And as Stein remarked, this development in metaphysics within physics continues: “One of the points about quantum field theory is that, in its domain, the necessary conceptual structure has not been found; I am tempted to say that the quantum theory of fields is the contemporary locus of metaphysical research” (ibid. 284-5).

And here we come full circle, back to the themes we discussed in regards to "Newtonian Space-Time", concerning the fruitful and productive role that metaphysics and epistemology have played, and continue to play, in physical theory and its development. Stein's vision of this relationship has inspired every subsequent generation of philosophers of physics to look to physics not as a source of "answers" to philosophical problems, but as a place where novel and important philosophical questions are constantly appearing, and as a guide to how to begin to develop fruitful ways to approaching the investigation of those questions.

These papers on the development of electromagnetism were also the foundation for one of Stein's most influential contributions to general philosophy of science—namely, to the realism/instrumentalism debate. There is a certain irony, here, because Stein's only published article on this subject—his "Yes, but...: Some Skeptical Remarks on Realism and Anti-Realism", published in *Dialectica* in 1989—is explicitly deflationary. In it he argues that the debate is not well-posed, and that there is "no difference that *makes* a difference" between "a cogent and enlightened 'realism' and a sophisticated 'instrumentalism'" (p. 61). One of his primary examples is the æther we have been discussing: it is common among anti-realists, he notes, to argue that "æther" is no longer taken to refer to any physical entity, and so for this reason æther theories make false ontological claims about the world. But this position, he argues, obscures the deep structural continuity between the late 19th century formulations of electromagnetism that invoked an æther and the theory as understood post-Einstein. Conversely, to counter such arguments by emphasizing that we continue to use the word "atom" today is likewise to obscure how dramatically our understanding of atoms has changed over the last two thousand years.

To understand the significance of "Yes, but...", one needs to understand its context. The volume of *Dialectica* in which the paper was published contained the proceedings of the meeting "Realism Today", held in Neuchâtel, Switzerland in May 1988. Among the speakers were Richard Boyd, William Newton-Smith, and John Worrall—who gave the now-famous paper "Structural Realism: The Best of Both Worlds?" introducing structural realism. Structural realism has undoubtedly been one of the most influential and widely discussed topics in philosophy of science for 30 years. In conversation with one of us (Curiel) some years ago, Worrall remarked that he credited Stein with the formulation of structural realism in the papers on 19th century science described above—and even in "Yes, but...", which was read at the meeting. Likewise, in the Stanford Encyclopedia entry on Structural Realism, James Ladyman, attributes key insights in the history of structural realism to Stein, particularly noting that Stein in several places suggests that space-time is best understood not as a substance nor a set of relations, but as a novel structure in its own right. Although Stein never identified as a structural realist in print (nor, we suspect, would he if asked), there can be little doubt that his distinctive understanding of how the mathematical and conceptual apparatus of physics finds representational significance, and how that significance evolves with the science, has had a strong influence on the development of realism in the last three decades.

We could continue to discuss Stein's work across other fields—the philosophy of mathematics, for instance, or the foundations of quantum mechanics—but we will leave these topics to the supporting letters. We conclude by bringing in another voice: that of Abner Shimony, Stein's long-time friend and collaborator. (Stein and Shimony first met in 1950, when they were both MA students at the University of Chicago, attending Carnap's famous seminar.) Shimony would have been a natural candidate to write a supporting letter for the nomination, but that is no longer possible. In lieu of such a letter, we quote from Shimony's introduction to the Festschrift for Stein, *Reading Natural Philosophy: Essays in the History and Philosophy of Science and Mathematics*, in which he admirably sums up Stein's breadth and depth, and his inimitable way of drawing upon all resources in his investigations and arguments.

> The publication of this Festschrift to Howard Stein is an occasion for celebration in several professions: philosophy of science, history of science, general philosophy (especially epistemology, methodology, and metaphysics), and physics. His masterful interweaving of considerations commonly parceled out to these disciplines is a major reason for the unique value of his papers.... In a highly competitive world, his choice of understanding over the prestige of discovery is extremely rare. But I am happy to say that his virtue was rewarded, for his passion to understand passages that have been dismissed as idiosyncratic or naive in classical writings (*e.g.*, Newton's "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external") has often led him to fine innovations of interpretation and in some cases to genuine conceptual discoveries.... Howard Stein's world view is one (of a rather large family) that regards successful natural sciences as revealing approximately the real structure of the world, recognizes the role of common sense in the initiation of scientific investigation, and acknowledges the great discrepancies between common sense and current scientific theory....

He goes on to discuss his own choice example of Stein's remarkable work: his article "On Relativity Theory and Openness of the Future". Shimony evaluates the attempt thus: "I consider this analysis to be a gem of naturalistic epistemology."

In sum, we believe Stein's contributions and his lasting influence in philosophy of physics and philosophy of science make him as strong a candidate as possilbe for the Hempel Award. We urge the committee to give his candidacy the most serious consideration.

Yours,
Erik Curiel, Michael Friedman, David Malament and James Weatherall