Studies in History and Philosophy of Science 64 (2017) 38–52

Contents lists available at ScienceDirect

Studies in History and Philosophy of Science

journal homepage: www.elsevier.com/locate/shpsa

Fresnel's laws, *ceteris paribus*

Aaron Sidney Wright

Suppes Center for History and Philosophy of Science, Stanford University, 450 Serra Mall, Main Quad, Building 90, Stanford, CA 94305, USA

ARTICLE INFO

Article history:
Received 16 December 2016
Received in revised form
21 June 2017
Available online 13 September 2017

ABSTRACT

This article is about structural realism, historical continuity, laws of nature, and *ceteris paribus* clauses. Fresnel's Laws of optics support Structural Realism because they are a scientific structure that has survived theory change. However, the history of Fresnel's Laws which has been depicted in debates over realism since the 1980s is badly distorted. Specifically, claims that J. C. Maxwell or his followers believed in an ontologically-subsistent electromagnetic field, and gave up the aether, before Einstein's *annus mirabilis* in 1905 are indefensible. Related claims that Maxwell himself did not believe in a luminiferous aether are also indefensible. This paper corrects the record. In order to trace Fresnel's Laws across significant ontological changes, they must be followed past Einstein into modern physics and nonlinear optics. I develop the philosophical implications of a more accurate history, and analyze Fresnel's Laws' historical trajectory in terms of dynamic *ceteris paribus* clauses. Structuralists have not embraced *ceteris paribus* laws, but they continue to point to Fresnel's Laws to resist anti-realist arguments from theory change. Fresnel's Laws fit the standard definition of a *ceteris paribus* law as a law applicable only in particular circumstances. Realists who appeal to the historical continuity of Fresnel's Laws to combat anti-realists must incorporate *ceteris paribus* laws into their metaphysics.

1. Introduction

If a science professor stops her philosopher colleague in the hall and they begin to discuss the scientist's picture of the world, what sort of objections could the philosopher make if they were unhappy with references to organisms and species, or to quantum fields and symmetry groups? If this philosopher has naturalistic leanings, there are three possible paths. *Epistemological* objections challenge scientists' access to the putative entities which they study. For example, Ian Hacking (1989) argued that astrophysicists' studies of black holes are so dependent on human assumptions and models that we should not accept that black holes have a mind independent existence. *Social* objections challenge the rationality or effectiveness of scientists' consensus formation. For example, the sociologist Harry Collins (1985) argued that experimental replications are question begging because the standard for a properly functioning instrument is its capacity to replicate the phenomena in question (Godin & Gingras, 2002). *Historical* objections ask why a philosopher should believe their colleague now, when science's picture of the world has changed so often? What will the picture be next year? Larry Laudan (1981) formulated this challenge as a Pessimistic Metainduction (PMI; "meta" because he thought the underlying theories were inductive.) What is the best defence the scientist can make?

This paper is concerned with the *historical* challenge to believing in scientists' pictures of the world. It seeks a realist's response to a skeptical historicist. In order to specify the nature of this challenge, philosophers have appealed to a range of theories about science itself. Thomas Kuhn saw scientists as working within wordviews (*weltanschauungen*) which affected their research at the level of individual psychology, as well as at the level of communal values, ideologies, and institutions (Kuhn, [1962] 1996, [1970] 1977). This picture is holistic and not well suited to formal analysis. Alternatively, formal analyses of science break it into pieces, such as sciences, fields, subfields, and individual theories, which are further divided into logical elements such as axioms, models of those axioms, and representation theorems which connect models to the world (Suppes, 2002; ch. 1). In the tradition of Logical Positivism, they are less concerned with metaphysical worldviews than with the structure of scientific reasoning, such as explanation. I will discuss Carl Hempel and Paul Oppenheim's paradigmatic "Studies in the Logic of Explanation" (1948) below. Elements from both the holistic worldview image of science and the formal image of science are at play in the debate over historical challenges to scientific realism.

Laudan's PMI is formulated in terms of a formal concept of scientific theories as consisting of sentences with theoretical terms

E-mail address: aswright@stanford.edu.

http://dx.doi.org/10.1016/j.shpsa.2017.07.008
0039-3681/

such as "phlogiston," "aether," "caloric," "humour," etc.[1] According to contemporary sciences, these terms no longer "refer"; that is, scientists no longer interpret these terms as referring to an entity in the world. Hilary Putnam put the argument in terms of terms:

> *just as no term used in the science of more than 50 (or whatever) years ago referred, so it will turn out that no term used now […] refers.*

Even if the empirical content of past theories is (approximately) included in newer theories, there is no guarantee that the terms in the old theory would have referents in the newer theory (Putnam, 1975, pp. 184, 180).

Putnam's solution to this problem appealed to both the formal- and worldview-images of science. He made concessions to the historicist argument, but sought to save scientific realism nonetheless. He gave up the possibility that terms like "ether" or "phlogiston" could refer. But he insisted that all the historical terms of past science were not alike—we continue to use some today:

> it is a fact that we can assign a referent to "gravitational field" in Newtonian theory *from the standpoint of* Relativity theory (though not to "ether" or "phlogiston") […].

Putnam argued that the acceptability of his limited realism about referents of theoretical terms depended on general epistemological commitments about knowledge and knowledge acquisition.

> These retrospective reference assignments depend on a principle that has been called the "Principle of Charity" or the "Principle of Benefit of the Doubt"; but not on *unreasonable* "charity". Surely the "gene" discussed in molecular biology is the gene (or rather "factor") Mendel intended to talk about; it is certainly what he should have *intended* to talk about! (Putnam, 1975, 180–81)

Here is where the holistic worldview image of science enters. The impact of general philosophical commitments on scientists' interpretation of evidence is a central feature of anti-realist argument. It questions the mind-independence of scientific reality. Could Einstein have convinced Newton to see gravity in a twentieth-century way? Did the two men's meta-scientific ideas about evidence and argument align? Putnam needed the answer to be "yes." Then he could say that the term "gravity" *referred* for both Newton and Einstein.

Against this thread of debate, John Worrall (1989b) made an influential argument for realism about scientific *structures*, such as laws of nature. He was not convinced that a realist could save the putative referents of scientific terms from the PMI, and he made his peace with what he thought survived across the centuries: the structure of the relations between the terms, regardless of what they stood for. In a philosophical sense Worrall took history quite seriously. He thought that the question of what survived theory change—the question of whether science in some sense progresses despite breaks—was "*prior*" to formal concerns about, say, approximate truth: "Unless this [pessimistic] picture of theory-change is shown to be inaccurate, then realism is surely untenable" (Worrall, 1989b, pp. 105, 109). Instead of focusing on the dustbin of the history of science (caloric, aether …), he focused on the monuments. Against pessimism, optimism (Worrall, 1994). If theoretical terms did not survive scientific revolutions with their referring relations intact, philosophers should focus on what did survive (at least approximately). Newton's laws of motion and of gravity were developed in the Scientific Revolution and hold as approximations in current scientific theory. Worrall's strongest—and most influential—historical example came from nineteenth century optics and the proposal that light was a wave-phenomena in a medium, the luminiferous aether: Augustin Fresnel's Laws of the reflection and refraction of polarized light. According to Worrall, "continuity [across theoretical change] is one of form or structure, not of content" (Worrall, 1989b, p. 117).

On one hand, Worrall gave up much more to historicists than Putnam did. Worrall gave up terms and reference. While Putnam tried to find a principled way to distinguish Newton's "gravity" from his "aether," Worrall was willing to allow neutrality about the entities which were attached to theoretical terms. Today, his proposal is called "Epistemic" Structural Realism (ESR) because Worrall allows that there are ontologically-fundamental objects (or perhaps kinds, powers, etc.) beyond structures, but ESR denies that we have access to this level (Ladyman, 1998). Whether "aether," "field," or "electron" feature in laws of nature, ESR sees limits to our ability to know whether theoretical terms truly refer. James Ladyman and Steven French have been the most prominent proponents of an "Ontic" Structural Realism, which put structures at the fundamental ontological level. In its most "eliminative" strain, they argue that structures are the *only* fundamental entities (Ladyman, 2009). SR does not satisfy realists who desire a more straightforward acceptance of the "face-value" of scientists' descriptions of the world (Putnam, 1975, p. 193; Psillos calls this the realists' "semantic thesis" in Psillos, 2005, p. 385).

On the other hand, SR can present a much stronger challenge to antirealist arguments which are based on the worldview image of science.[2] In SR, whether Fresnel believed in a material aether which was the medium of light propagation—whether he *intended* to study aethers, or action-at-a-distance, etc.—is irrelevant to the robustness of his laws throughout history.[3] Putnam needed to borrow from the worldview image of science in order to combat a pessimistic reading of the history of science. Structuralists need not.

In order to maintain its distance from a holistic worldview image of science, SR needs to find a contemporary understanding of "scientific structure" which can be applied to past theories, and then show that such structures survived "radical" theory change, such as Kuhn's scientific revolutions. Structuralists do *not* need their notion of structure to be possibly acceptable to long-dead scientists. As such, they do not need to rely on the sort of trans-historical philosophical commitments to which Putnam appealed. Posit for the moment that the historical case for continuity of structure can be made. The force of Laudan's PMI rests on a twentieth-century formulation of scientific theories as logical/linguistic entities. Any anti-realist who accepts a *pessimistic* induction which is based on contemporary philosophy of science must also accept an *optimistic* induction which is based on contemporary philosophy of science (cf. Worrall, 1994). This also applies to term-reference critiques which are not "inductions" (Feyerabend, 1962; Ladyman & Ross, 2007, pp. 91–93). Even the most committed, holistic, worldview-based critique cannot contest that historical arguments are structured by the era in which they were written (Biagioli, 1996; Iggers, 2005). In this way, structural realism with a

[1] In contrast, Paul Feyerabend's similar arguments were closer to Kuhn's worldview approach (Feyerabend, [1975] 2010).

[2] Over time, Worrall has framed SR as more or less dependent or independent of scientists' mindset. This is related to his view of the importance of novel predictions in the acceptance of scientific theories. See Brush, 2007; Stanford, 2003a.

[3] It may be that Fresnel's commitment to the aether helped or hindered the reception of his views. My point here is that there is a historical fact of the matter that Fresnel's Laws were part of the "mature" science of optics from the 1820s, across the modern abandonment of the material aether, to today. Jed Buchwald's detailed study of this period places the emphasis away from abstract theories, and toward concepts and methods which were closer to experimental practice: Buchwald, 1989, 1992.