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Reconsidering Structural Realism

DAN McARTHUR
Queen's University
Kingston, ON
Canada K1R 5M8

Introduction

In the lengthy debate over the question of scientific realism one of the least discussed positions is structural realism. However, this position ought to attract critical attention because it purports to preserve the central insights of the best arguments for both realism and anti-realism. John Worrall has in fact described it as being 'the best of both worlds' that recognizes the discontinuous nature of scientific change as well as the 'no-miracles' argument for scientific realism.[1] However, the validity of this claim has been called into question by Stathis Psillos. He questions its ability to correctly account for the examples of scientific change that its supporters, like Worrall (following Poincaré), claim ought to be understood in a structural realist light.

In this paper I examine these arguments for and against structural realism and demonstrate that neither Worrall nor Psillos is fully correct. I agree with Psillos' claim that realism with regards to a theory ought not to be 'all or nothing,' that one should not always take the whole of a theory to be true or else commit only to the belief in its directly empirical content.[2] However, I contend that this view is consistent with recent

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1 J. Worrall, 'Structural Realism: The Best of Both Worlds,' *Dialectica* **43** (1989) 99-124, at 99

2 S. Psillos, 'Is Structural Realism the Best of Both Worlds?' *Dialectica* **49** (1995) 15-46, at 44

deflationary approaches to the realism question and that such a view leaves a large role for structural realism as a fruitful way to interpret theories, including the examples provided by Worrall in structural realism's defense.

In order to make this case, this paper is organized as follows. First, I will provide an overview of structural realism and outline the cases for and against it, drawing primarily from the arguments of Worrall and Psillos. Second, I will re-examine the main scientific example that is the locus of debate for both, the incorporation of Fresnel's equations into Maxwell's electromagnetic theory. I argue that while structural realism is not always the best of both worlds, there are particular cases in which it is. I conclude, from a deflationary perspective, that while structural realism cannot finally solve the realism question for every theory whose interpretative status in doubt, it can often prove to be a fruitful tool for interpreting scientific theories, including the Fresnel/Maxwell case.

I For and Against Structural Realism

Structural realism essentially holds that belief in the constituents of a scientific theory that transcend its immediate empirical content is unwarranted. The rationally behind this is that this content is usually dramatically re-conceptualized if not abandoned when theories change. A fairly classical example of this is the elastic ether which played a major role in Fresnel's theory, but is abandoned by Maxwell's theory which superceded Fresnel's. Laudan has in fact assembled a large list of such entities, such as phlogiston and caloric that once played large roles in empirically well confirmed, and indeed predictively successful, theories that have since been totally abandoned.[3] Since there is no way to know if today's unobservable content, like quarks, might not someday go the way of the ether, especially if this content is underdetermined by the evidence (which is nearly always the case), philosophers must remain agnostic about this content.

In this sense, structural realism is not compatible with the sort of realist position typified by the arguments of a large number of philosophers[4]

3 Cf. L. Laudan, 'The Confutation of Convergent Realism,' in J. Leplin, ed., *Scientific Realism* (Berkeley: University of California Press 1984).

4 E.g. R. Boyd, 'Realism, Underdetermination and a Causal Theory of Evidence,' *Nous* **7** (1973) 1-12, and 'Scientific Realism and Naturalistic Epistemology,' *Philosophy of Science Association* **2** (1981) 613-62; M. Devitt, *Realism and Truth* (Oxford: Blackwell 1994); H. Putnam, *Mathematics, Matter, and Method* (Cambridge, MA: Cambridge

who hold that belief in (at least) the approximate truth of such content is warranted. In spite of its rejection of this cardinal plank in the realist platform, structural realism is not identical to a position like van Fraassen's constructive empiricism,[5] which recommends a similar agnosticism about unobservable content. The reason for this is that the structural realist believes in some type of continuity of content between newer theories and theories that were once empirically successful, but now abandoned, such as those that refer to non-existent phenomena like caloric or the ether.

1. The case for structural realism

The chief case for structural realism has come from instances of theory change which, structural realists claim, are best accounted for by their view. As one of the central recent proponents, John Worrall, argues, 'there was continuity or accumulation in the shift [between theories], but the continuity is one of *form* or *structure*, not of content' (Worrall, 'Structural Realism,' 117). A theory like Fresnel's theory of light may not have been true in terms of what it took light to be (waves through the ether), but Fresnel was correct (to a point) because he 'attributed to light the right *structure*' (Worrall, 'Structural Realism,' 117). In other words, in Worrall's view, while Fresnel may not have been correct that light is a wave travelling through the elastic ether, his equations that describe how light propagates through the ether correctly describe how light propagates. Thus, Fresnel's equations can be retained in Maxwell's electromagnetic theory of light which abandons reference to the elastic ether and conceives of light in very different terms, i.e. as a wave propagating through an electromagnetic field.

Given the above considerations, Psillos argues that the main features of structural realism can be neatly summarized as follows.

> a) Scientific theories, at best, reveal the logical form or structure of the underlying physical reality by means of mathematical structure.
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> b) Mathematical equations which are retained in theory change express real relations between objects for which we know nothing more than they stand in these relations to one another.
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> c) Different ontologies may satisfy the same mathematical structure but there are no reasons to believe in one of those as the correct one. (Psillos, 'Is Structural Realism the Best?' 20)

University Press 1975); W. Sellars, *Science, Perception, and Reality* (London: Routledge and Kegan Paul 1963)

5 Cf. B. van Fraassen, *The Scientific Image* (Oxford: Oxford University Press 1980).

The position, as Psillos claims, is a skeptical one because for the structural realist not only are the entities referred to by an older theory not retained by its replacements, but even the constituents of current theory do not warrant belief as approximately true. Nevertheless, according to Worrall, there is still much for the realist to find solace in. The reason for this is because the retained structural (i.e. mathematical) content is sufficient to take account of what is plausible from the strongest case for realism, the so-called *no-miracles* argument.

The no-miracles argument is associated with Putnam, but had actually already been articulated by Smart before Putnam.[6] It states that the great success of current well accepted scientific theories stands in need of explanation. The truth or approximate truth of a theory must, in this view, count as a better explanation for its success than pure chance or a 'miracle.' As Worrall puts it,

> it is plausible to conclude that presently accepted theories are indeed ''essentially'' correct. After all, quantum theory gets certain phenomena, like the ''Lamb shift,'' correct to, whatever it is, six or seven decimal places; in the view of some scientists, only a philosopher, overly impressed by merely logical possibilities, could believe that this is compatible with quantum theory's failing to be a fundamentally correct description of reality. (Worrall, 'Structural Realism,' 101)

To be a little more precise, the portion of a theory whose success stands in need of explanation is not, of course, that portion of a theory's mathematical structure that was retained from an old theory. What must be explained is the new structure. After all, 'it is no miracle if a theory gets a fact right which was already known to hold and which the theory had been engineered to yield' (Worrall, 'Structural Realism,' 101).

So in Worrall's view what is 'essentially' correct about current theory is not the constituents named by current theory, as this content can easily someday go the way of caloric or the ether and can be under-determined by the evidence in any case. What is essentially correct is, at least, some of the mathematical structure. This, in the observational settings accounted for by the theory, in order for success not to be seen as purely coincidental, must approximate the relations that obtain between whatever does exist, however we may choose to describe that. With regard to theory change, then, these portions of a theory's mathematical structure that are carried over into new theory can be held to be approximately true. The same applies to the content of current theory. The empirically successful mathematical structure that is new, i.e. that describes phe-

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6 Cf. J.C. Smart, *Philosophy and Scientific Realism* (London: RK Press 1963).

nomena successfully, is essentially correct. This is most likely to be retained in an eventual theory change.

As I have already mentioned, the central example used by Worrall to illustrate his view is the retention of some of Fresnel's equations in Maxwell's theory of light. Additionally, Worrall focuses on this example because it is drawn from Poincaré's[7] analysis, which Worrall identifies as the origin of his own position. Moreover, as Psillos contends that an examination of this very same case supports a traditionally realist, rather than structural realist, interpretation, it is worth providing a more detailed summary of Worrall's reading of the case.

As we have already seen, Fresnel conceptualized light as a wave that propagates through the elastic medium of the ether. More specifically, Fresnel's theory interprets light as a displacement of particles in the ether, the intensity relating to the magnitude of the displacement. Central to the empirical success of the theory is the conception of light as propagating along the direction of incidence and at right angles to it. In the case of non-polarized light, this propagation occurs along every plane perpendicular to the direction of incidence. This conception permits, among other things, Fresnel's famous prediction of a white spot in the centre of a disk struck by light diverging from a single slit (Worrall, 'Structural Realism,' 116).

Maxwell's theory of light retains Fresnel's equations that describe this propagation at right angles to the direction of incidence. However, in Maxwell's theory there is no elastic ether, but instead a 'disembodied' electric field. Thus, in Maxwell's theory the terms in Fresnel's equations that refer to the amplitude of the vibration of the particles of the elastic ether are re-interpreted as referring to the changes in the electric and magnetic field strengths. There are no displaced particles in Maxwell's theory, as light is, in this interpretation, a displacement current in the disembodied electromagnetic field. The referents of the terms in Fresnel's equations by no means 'approximate' the referents of Maxwell's terms. Of course, the ether does have a role in Maxwell's theory, and Psillos has described this in some detail recently.[8] Nevertheless, the ether's properties cannot be said to exactly duplicate (in Fresnel's theory) the properties of Maxwell's electromagnetic field. The ether has parts; it is composed of particles and possesses elastic restoring forces that return

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7 H. Poincare, 'Science and Hypothesis,' reprinted in *The Foundations of Science* (Lancaster: The Science Press 1913)

8 Cf. S. Psillos, *Scientific Realism: How Science Tracks Truth* (London: Routledge 1999), 137-40 and 296-8.

the particles to their positions. Nothing of the kind is included in the electromagnetic field. Nothing is in fact physically displaced in Maxwell's theory. What 'vibrates' in the propagating light wave is charge strength. For Worrall, with regard to the physical interpretation of light, then, 'if later science is right, Fresnel is wrong' (Worrall, 'Structural Realism,' 117).

In the change from Fresnel's to Maxwell's theory of light very little is retained and nothing whatever concerning the ether and its properties. Even the propagation of light is conceived differently, not just the medium through which it propagates. However, even though the interpretation of nearly every term in Fresnel's equations is re-conceived, the equations themselves are retained. For Worrall, then, the relations expressed by these equations are real, even if the physical interpretation of what is so related is not. In Worrall's terms, not only is Fresnel's theory empirically adequate to predict optical phenomena, but it is 'right that these phenomena depend on something or other that undergoes periodic change at right angles to the light' (Worrall, 'Structural Realism,' 120). Thus Fresnel's equations are retained in Maxwell's theory because they express the periodic changes that actually do take place at right angles to the light, even though Fresnel was incorrect about what changes in the periodic manner described.

2. The case against structural realism

Psillos, as we have seen, expresses doubt about both the structural realist reading of the Fresnel-Maxwell case and structural realism's general utility as a means for accounting for theory change. With regard to structural realism in general, Psillos advances two arguments to support his doubts. First he contends that Worrall's claim that structural realism is a viable middle ground between realism and anti-realism requires more resources than are available to structural realism. As a result, it is unable to offer an adequate response to skeptical criticism that might come from a position like van Fraassen's. Second, Psillos contends that structural realism depends on an untenable distinction between structure and nature.

Psillos' analysis of the Maxwell/Fresnel case rests on the two general objections to structural realism noted above. According to Psillos, structural realism concurs with anti-realism with regard to the status of unobservable. In this sense it is similar to a view like van Fraassen's. Of course, structural realism does not recommend such anti-realist agnosticism about structure. However, even if a clear distinction between structure and nature is granted, the structural realists must augment their position by providing a rebuttal to anti-realist agnosticism about structure. This is so because a view like van Fraassen's may be used to recommend agnosticism about both structure and nature. As the structural realist wishes to limit agnosticism to merely the nature of theoretical referents, she must offer reasons why agnosticism ought to be so limited.[9]

Worrall, of course, does offer two related justifications for not accepting agnosticism about structure. The first is simply the observation that structure is retained across instances of theory change, and this observation is, of course, central to structural realism. Structural realism is, in fact, exactly the recognition of this fact. However, Psillos, following Laudan, finds this observation insufficient to sustain any sort of realist position. The retention of equations, for an anti-realist, might simply represent only 'a pragmatic consideration' and simply be 'labor saving to build upon the mathematical work of predecessors.'[10]

The second of Worrall's reasons for non-agnosticism about structure is, naturally enough, the no-miracles argument. The reason why equations can be successfully retained is because they actually represent true relations. Such an explanation seems, in this view, more satisfactory than viewing successful retention as simply a happy coincidence. However, as Psillos notes, the structural realist version of the no-miracles argument is somewhat weaker than the traditional realist version as it hesitates to ascribe approximate truth to superceded theories, attributing only structural adequacy. Worrall notes that the classical wave theory of light is 'to some extent *structurally* adequate, no doubt, but ''approximately true'' — no.'[11]

However, for several reasons, Psillos rejects this weaker version of the structural realist version of the no-miracles argument. According to Psillos, if the retention of empirically successful equations is to support structural realism, then one must also contend that only this structural content helps explain the empirical success. However, Psillos insists, uninterpreted structure alone is not enough to produce predictions. Thus, if predictive empirical success is to be accounted for, then the no-miracles argument relies on an 'implicit inference to the best explanation.'[12] However, such an appeal lies at the heart of realist claims to

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9 Cf. Psillos, 'Is Structural Realism the Best?' 27.

10 S. Psillos, 'Is Structural Realism the Best?' 26

11 J. Worrall, 'Scientific Revolutions and Scientific Rationality: The Case of ''Elderly Holdout,'''in C.W. Savage, ed., *Scientific Theories*, *Minnesota Studies in the Philosophy of Science* **14** (1990), 343

12 S. Psillos, 'Is Structural Realism the Best?' 29

the effect that approximate truth is the best explanation for empirical success.

For Psillos, philosophers like van Fraassen and Laudan who have expressed skepticism about inference to the best explanation will probably find structural realism's just slightly more cautious use of it unconvincing. The central difference between the structural and ordinary realist, seen this way, is simply the amount of unobservable content they are willing to assent to being approximately true. The ordinary realist is hardly bound to claim belief in all unobservable content, so from the point of view of an anti-realist, little difference exists between their claims. Psillos notes, 'I cannot see why Laudan would be moved by weak and unsupported considerations if he is not already moved by a more rigorous formulation of the ''no-miracles'' argument.'[13]

However, the strongest objection that Psillos advances against structural realism is his second main objection noted above, i.e. that it relies on what he takes to be a false distinction between structure and nature. Psillos has two related objections to this distinction. His first is that structure and nature are not distinct but in fact form a continuum. His second is that we can come to have at least some knowledge of unobservable nature, as opposed to structure. In fact, according to Psillos, discussing structure and nature as entirely distinct renders the notion of nature entirely obscure. As Psillos notes, 'when scientists talk about nature what is normally understood is a bunch of basic properties and a set of equations, expressing laws' (ibid.). In other words, most of what can be considered as the 'nature' of an entity is also expressed in equations about structural content. The notion that there is a nature that transcends structure that can be investigated empirically and expressed in equations, for Psillos, is reminiscent of medieval conceptions of 'forms' and 'structures.' Such notions, of course, are no longer part of the corpus of science. As Psillos reads structural realism, that position posits just such entities and then denies that they can be investigated empirically, encapsulated mathematically, or that they can be the subject of scientific laws. There is an ironic sense in which Psillos sees traditional realism as *less* metaphysical than structural realism, having abandoned all reference to medieval 'substances.' Although the realist does see all of scientific posits as the subject, at least in principle, of knowledge and belief. The structural realist position then, is implausible from this point of view, a superior view being that structure and content overlap and that learning more about the nature of something involves exactly

13 S. Psillos, 'Is Structural Realism the Best?' 31

discovering what laws express this content. In this sense mathematical structure and the 'nature' of that structure form a continuum in so far as such non-structural components of a theory are at least potentially expressible as mathematical laws. That is to say, learning more about the laws an entity obeys and refining existing ones is precisely what scientific progress amounts to.

Psillos uses this analysis of the distinction between structure and nature to criticize Poincaré's and Worrall's reading of the Fresnel/Maxwell case. Essentially, he contends that it was not only structure that was carried over in this example of theory change. More specifically he contends that part of what is retained in Maxwell's theory of light is Fresnel's account of the transversal nature of light. Thus not only are equations retained, but something of their interpretation as well.

For Psillos, this transversal character is a fundamental part of light's nature. Moreover, the fact that Fresnel believed that light propagates in this way by displacing molecules in the elastic ether is a fairly inessential feature of his theory with respect to its mathematical structure, empirical success, and its derivation of light's transversal character. In this view the ether simply serves as a convenient medium for the light to propagate through. Fresnel was, however, correct about much of the nature of light in so far as he was correct that it requires a medium to propagate through, that it travels at a finite speed and that its propagation obeys certain laws which he identified. Such a view is in keeping with Psillos' contention that structure and nature blend into each other as a large portion of what can described as something's 'nature' are the laws that it obeys. In the Fresnel case, for Psillos, much of this content was in fact retained.

II Structural Realism Defended

In spite of his claims to the contrary, the structural realist can respond to Psillos' criticism. Consider the claim that structural realism cannot sustain its claim against agnosticism about structural content. Psillos denies that structural realism's recourse to the no-miracles argument is more convincing to the anti-realist than when deployed by the traditional realist. Why, he asks, might a philosopher like van Fraassen rescind skepticism about structural content when he would not be convinced about the plausibility of belief in unobservable content in general? However, I think that Psillos has misrepresented the nature of the structural realist use of the no-miracles argument.

1. The structural realist no-miracles argument

The anti-realist rejection of the no-miracles argument is organized around the fact that much formerly accepted scientific content does not survive theory change. However, the structural realist is not simply asking that the anti-realist mitigate agnosticism in one small domain of that content. The structural realist is, in fact, drawing to a large extent on the anti-realist observation that concepts are replaced when theory change takes place. The structural realist, then, is simply drawing attention to the fact that some mathematical structure does survive theory change and that this fact stands in need of explanation. It is true, to this extent, that the structural realist does implicitly appeal to an inference to the best explanation, but this appeal is not quite the same as the realist's.

Psillos claims that for the structural realist arguments to hold water, only structural content can explain the empirical success of theories. But for Psillos, no justification can be given for so limiting the explanation of this success to structural and mathematical features, thus making the no-miracles point equally available to the traditional realist. However, the structural realist does not appeal to her view to simply explain the empirical success of current theory. The structural realist is in fact accepting the anti-realist view that the content, whose truth is usually defended with the no-miracles argument, is often not retained in theory change. What the structural realist is claiming is that structural realism is the best explanation for the empirically successful retention of mathematical structure from one theory to the next.

The retention of the empirical consequences of an old theory, of course, is no mystery since new theories have to be as empirically successful as their predecessors. What the structural realist claims to account for is the use of old equations in new theories that generate new empirical successes. Thus the structural realist appeal to the no-miracles argument does not take the traditional realist form that empirical success is 'no miracle' but that empirical successes in the context of the retention of old structural content is 'no miracle.' The basis of structural realism, then, is not just a weaker version of the no-miracles argument, oddly limited to structural content, but the empirical fact that such content is retained in theory change. Thus the structural realist is not just asking the anti-realist to accept a slightly weaker no-miracles argument. The structural realist move is, in fact, to accept the general anti-realist rejection of traditional realism while pointing out that such a rejection must also be able to account for retained structural content. Since, the argument goes, it is a clear fact that such content alone is retained and structural realism accommodates this fact, and realism and anti-realism do not, structural realism becomes a plausible alternative to both positions.

If an anti-realist were to accept the structural realist claim that such mathematical structure is retained (e.g. in a case like the Fresnel/Maxwell theory change) then structural realism might well seem a more plausible view than traditional realism. The traditional realist's no-miracles argument seeks to account for the empirical success of current theory, claiming that the anti-realist pessimism about meta-induction does not. It does not, however, deal with the genuine issue of theory change in a wholly satisfactory way. Arguing that 'successful current theory would not be explicable unless approximately true' does not offer an explanation for the aspect of theory change structural realism focuses on, retained mathematical structure. Since retained structural content is the locus of interest in theory change, very good reasons exist to focus on this content rather than the non-structural, non-retained content that is appealed to by the realist.

Of course this rebuttal to criticisms of the structural realist use of the no-miracles argument assumes that there is a clear distinction between structure and nature. Nevertheless, as Psillos points out, his criticism of structural realist recourse to the no-miracles argument is supposed to be sound even if the validity of the distinction is granted. However, it is clear that this is not so. Trenchant criticism of structural realism, then, must focus on the validity of its central distinction between structure and nature. And as we have seen, Psillos directs his main criticism against exactly this distinction. And, if my subsequent arguments are sound, then it will become clear that Psillos's arguments against it are wanting.

2. The structure/nature distinction

The core of Psillos's objection to the structural realist distinction is that structure and nature form a continuum. The central idea here being the fact that a great deal of what can be plausibly called 'nature' is expressed elsewhere structurally. Moreover, conceptions of nature that go 'beyond' this are deeply implausible since they hearken back to very obsolete medieval conceptions of nature that have been repudiated since the scientific revolution of Newton's day and before.

This latter claim, however, considerably misrepresents the nature of the structural realist position. Presented this way, structural realism seems to posit highly dubious and old-fashioned metaphysics that plays no role in modern science at all. This position is a slow moving target indeed, but it is hardly what the structural realist actually maintains. Psillos contends, against structural realism, that what is meant by the nature of something is some basic properties and some basic laws (expressed as equations) that the properties obey. But this view of structural realism is quite inconsistent with the view as it is presented by Worrall or Poincaré. In fact, it is not at all clear that 'nature' as it is construed by Psillos differs greatly from the structural realist view.

Consider yet again the structural realist reading of Fresnel's account of the 'nature' of light. The structure of light's propagation is expressed, of course, in Fresnel's equations, but the light that so propagates is taken to be perturbations in the molecules of the ether. Light is seen as motion through the ether. However, the ether is described in terms of a few basic properties that obey certain laws that can be expressed as equations. In this case the basic properties of the ether are that it is elastic and that it is composed of particles. The amplitude expressed in the wave equations is supposed to correspond to the magnitude of the movement of molecules. Thus it obeys some mathematically expressible laws. There is no reference in this picture to an underlying 'essence' or substrate that cannot, even in principle, be investigated empirically or be the subject of scientific knowledge.

The key to understanding the structural realist interpretation of this instance of theory change rests in its deployment to account for the retention of old equations even though the interpretation of the referents of the terms of the equations undergoes considerable change. The fact that the interpretation of the nature of the referents both before and after the theory change makes no reference to dubious 'substances' or 'essences' hardly counts as an argument against structural realism. The structural realist can and does conceive of the *relata* in such relations without needing recourse to unknowable essences. Even if we assume for the sake of argument that the interpretation of the nature of the entities referred to in the retained relations are entirely definable 'structurally,' the structural realist can still make a considerable case for her position. This is so because the structural realist account of the theory change in question purports to provide an explanation for the retention of mathematical structure from the replaced theory. This still stands in need of explanation, even if after the theory change the interpretation of the referents of the equations is defined entirely in terms of other structural content in the new theory. In the Fresnel/Maxwell case, for example, this includes the properties and laws obeyed by the disembodied electromagnetic field.

Psillos contends that for both Fresnel and Maxwell what is key to the nature of light is its transversal character but not the medium through which it propagates.[14] There is no question that Psillos is correct that this aspect of light waves is very central in both theories, and he provides

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14 Cf. S. Psillos, 'Is Structural Realism the Best?' 34-5.

ample evidence for this. However, I doubt that Worrall or other structural realists would take any great exception to that observation. The point that needs to be made is that this transversal character is part of the theories' empirical content and is expressed structurally in the equations that are retained in the theory change. Light's transversal property is a law (expressed in equations) light obeys. However, the terms of the wave equations (e.g. the amplitude) are defined differently, and the definitions are not retained across the instance of theory change.

The point becomes even more clear when contemporary quantum mechanical theories of light are taken into account. Fresnel's theory can hardly be described as being 'approximately true' about light's nature being that of a transversal wave. It is true that on macroscopic scales, like the ones investigated in Maxwell's day, light obeys laws that average out to resemble the empirical consequences of the previous theories. But photons, individually, of course, are not transversal waves. Their nature is in fact extremely opaque and anything resembling a complete discussion is well beyond the scope of this paper. However, very briefly, the mainstream view (which is not uncontroversial) states that is it is not the photon that propagates transversally but the probability of its being found in a given location. Nevertheless, however the nature of light is interpreted according to quantum theory, it will not turn out to resemble the view of the previous theories. Viewed in the larger context, then, a traditional realist reading of the Fresnel/Maxwell instance of theory change breaks down and the utility of a structural realist account becomes apparent. While on certain scales light approximately behaves according to the older wave equations, contemporary views of its nature have completely changed. This, of course, is more in keeping with the structural realist reading than with the traditional realist reading.

Psillos certainly has a point, however, in his contention that structure and nature are connected in important ways. Nevertheless, his inaccurate presentation of the structural realist view of the distinction points to some difficulties with his own view. Essentially Psillos defines the 'nature' of a term or entity in large part by way of identifying structural laws that it obeys. Thus, he argues, structure and nature blur together and form a continuum. However, this view is not quite adequate to deal with instances of theory change like the Fresnel/Maxwell case where some mathematical structure is retained. The reason for this is that while Psillos can be correct that the referents of the terms of an equation might well be interpreted in terms of other laws that admit structural definition, this interpretation of a term does not necessarily survive theory change. This can be so even though the equation in which the term is deployed does.

What is at issue in instances of theory change, then, is not what constitutes the interpretation of the 'nature' of the referents of the terms in retained equations. What is at issue, for the structural realist, is that the interpretations, whatever they may be, change when the theories are replaced. While Psillos may be correct that a term's nature may be conceived within a theory as being constituted by other laws, a distinction between the interpretation of a term and the equations in which it is utilized can be drawn. In other words, with regard to the equations that are retained across instances of theory change, a distinction can be, in practice, drawn between an interpretation of a term and the equation within which it appears. What structural realism offers is an account of how the terms of equations can defined anew across such instances of theory change, even though the equations that the terms appear in are retained.

Seen this way a clear relationship does exist within a theory with regard to structure and nature, and the two are interrelated. However, in practice a distinction can be drawn between the interpretation of a term and an instance of its use. It is this distinction that is important for the structural realist account of theory change, not the relation between structure and nature that exists within a theory prior to its replacement. Psillos, then, has to a certain extent mis-focused his analysis. His analysis focuses on what he takes to be a great difference between the structural realist account of the interpretation of the referents of terms and the at least partially structural reading his analysis provides. But this does not adequately capture the distinction, identified above, that exists between the interpretation of a term and the structural context of its use.

The terms that make up retained equations and the interpretation of their referents are related. However, they are not best seen as forming a continuum. One useful way to conceptualize this relation might be to see it as a type/token relation. In this sense, the relations between terms in retained equations can be conceptualized as general types of relations that could accommodate many different instantiations. Thus the interpretations of, say, light as it appears in the Fresnel and Maxwell theories can usefully be seen as two different instances that express the type of relations represented by the equations in question. In Fresnel's case the transversal wave equations are interpreted as referring to waves through the elastic ether, the amplitude corresponding to the magnitude of the displacement of the ether's particles. Maxwell's theory, by contrast, instantiates this transversal relation type with a quite different token. Structural realist interpretations of theory change, then, can be a useful way of accounting for the retention of relation types in the context of instantiation with different tokens.

III Structural Realism From a Deflationary Perspective

I have tried to defend structural realism by clarifying its reading of the interpretation of terms in retained equations as a type/token relation. When so characterized, the structural realist account becomes useful in those instances where some mathematical structure is retained after a theory change in a context where the terms of these equations bear quite different interpretations. This sort of situation, of course, is quite common in the history of science. The Fresnel/Maxwell case has been the main focus of this paper and also of many of the other commentators I have cited. However, other examples are easily found. As I have already noted, quantum mechanical accounts of light average out to approximately correspond to the classical equations at macroscopic scales. In this case, too, the interpretation of light is profoundly re-conceptualized, this time in terms of agglomerations of photons with all of their attendant properties and laws (their behavior, en mass, averages out to Maxwell's equations of the scales he investigated). Other examples are readily found in the equations of classical physics that are retained for practical use in many everyday situations. Central concepts like mass are dramatically re-defined in contemporary relativistic physics; many new equations are being introduced that define mass very differently (and not as a conserved quantity). However, at the scales investigated by most pre-relativistic physics, pre-relativistic equations give results that are approximately true.

While I have contended that structural realism proves to be a useful way to interpret such cases, it does not follow from my arguments that every situation will be like this. Moreover, structural realism has little to say about the proper interpretation of the terms in current, unreplaced, and well-confirmed equations. And, of course, it is reasonable to expect that both philosophers and scientists alike will regard the constituents of current theory with variable commitment. This point is well appreciated by Psillos, who notes that it is not the case that 'one must believe everything that a scientific theory predicates of the world to an equal degree or, else, believe in nothing but observable phenomena.'[15] The deployment of structural realism to account for the retention of equations and not the interpretation of their terms is quite consistent with any number of positions with regard to the interpretation of the constituents

15 S. Psillos, 'Is Structural Realism the Best?' 44

of current theory. Seen in this light, structural realism becomes just one quite useful arrow in the philosopher's quiver.

Such a role for structural realism is in keeping with the increasingly popular deflationary approach to the scientific realism question. This view is well summarized by Psillos's observation noted above, that one does not either have to believe in all the constituents of an accepted theory or restrict belief only to observable content. The central point of such a view being that *a priori*, i.e. a global position, on the realism question is avoided, the correct stance in particular instances being established locally, depending on the details of the situation in question.[16] Structural realism, then, can be very useful from a deflationary point of view because it proves to be a useful way to regard certain structural constituents in current theory that have been retained from older previously replaced theory. Moreover, it also provides a useful way to analyze certain instances of theory change where the constituents of a theory are considerably re-conceptualized but at least some mathematical structure is retained. It also provides, as I have suggested, a useful way of conceptualizing the distinction between the interpretation of a theory's constituents and the context of their deployment, as a type/token distinction. That is, the type/token relation that I described above provides a clearer account of the central distinction of structural realism, rather than the problematic distinction between structure and nature that Psillos claims structural realism is tied to. Indeed, this account of structural realism's central distinction is related to a deflationary approach to theoretical terms. Nothing in the distinction as I have described it precludes scientists from taking any number of stances with regard to the truth of the characterizations of the terms used in the equations (old or new) that make up current well confirmed theory.

That said, the application of structural realism is limited and is of little assistance in helping to provide the best interpretation of the referents of the terms of equations used in current theory. Nothing in the structural realist view of theories precludes either a provisionally realist or, say, empiricist reading of this content. However, from a deflationary point of view, the correct stance to this content will not be monolithic. That is to say, some of this content will warrant realist belief and some will be best regarded in an anti-realist light. Structural realism, then, may find its place within the pluralist philosophical environment described by

16 Cf. S. Sismondo, 'Deflationary Metaphysics and the Construction of Laboratory Mice,' *Metaphilosophy* **28** (1997) 221-32, and D. McArthur, 'The Methodological Implications of Resolving the Realism Debate,' *Science Studies* **15** (2002) 59-78 for characteristic presentations of the view.

deflationary interpretations of science. If my above arguments are sound, then, while not perhaps providing a comprehensive solution to every situation where the question of scientific realism is in some way germane, they do provide useful resources to clarify our understanding of a large body of situations of a fairly common sort. Specifically, it is of great use in making sense of and explaining situations where at least some structural content from obsolete theories is successfully retained by later theories.

It might be objected that such a role for structural realism is not available in a deflationary context because structural realism is committed to a stronger body of claims than a deflationary view permits. Specifically, structural realism is committed to more than particular claims about the nature of retained structure, it also precludes belief in anything other than the structural content it addresses. This is, for example, more or less how Psillos reads structural realism. However, when structural realism is read in the way that I propose, the charge that it is irreconcilable with a deflationary approach does not hold.

It might well be the case that structural realism as it is characterized by Psillos is too skeptical a position to be reconciled with a deflationary view, but his characterization of the view is inaccurate. For Psillos, structural realism is organized around a distinction between structure and nature, wherein nature was taken to be wholly different and entirely distinct from structure and, from this point of view, nothing at all could be said about nature. If this were so, structural realism would not merely be silent about the interpretation of the nature of the entities that constitute current theory, it would preclude any discussion on the point. However, as we have seen, neither is this a good characterization of the structural realist view of the relation between structure and nature nor is that distinction the central distinction around which structural realism is organized. As I have characterized it, the main focus of structural realism is the distinction between the relations between the terms in the context of retained equations that employ them and the interpretations of these terms. Terms might well admit of redefinition and still stand in the same relation to each other in at least some equations that are retained across theory change. Seen this way, nothing would prevent, for example, a term that is part of a retained equation being redefined in terms of equations introduced by the new theory. While structural realism provides an explanation for the retention of the old equations, it need not, if my account is sound, prevent any re-assessment of the definition of such terms, or variation and revision in the degree of belief in the truth of such definitions.

Indeed, one useful result of viewing structural realism from such a deflationary perspective is that it helps us understand the relation between the sort of account I have been defending and recent writing on the subject by Ladyman and Psillos. Recently, Ladyman has tried to defend structural realism from charges that it is vacuous by drawing a distinction between two varieties: 'epistemological' and 'metaphysical.'[17] Ladyman accepts the charges made by Demopoulos and Friedman[18] that early forms of structural realism (like that advocated by Russell) are empty. That is, any two theories with the same empirical content can be given the same structure (i.e. they have the same Ramsey sentence), so claiming only structure can be known tells us little of value. This objection for Ladyman attaches to 'epistemological' structural realism: the view that the world is 'composed of unobservable objects' but only their logico-mathematical relations to each other can be known (Ladyman, 412). However, he claims, 'metaphysical' structural realism avoids the charges. Metaphysical structural realism takes structure to be ontologically primitive, where theories are seen as collections of models, not sets of sentences. Taking structure as primitive and taking a 'no-statement' view of theories instead of seeing them as sets of sentences, he claims, will avoid the objection that structural realism is empty.

Psillos has recently argued that Ladyman's view is untenable since it is difficult to make sense of how we could talk of structures being related (e.g. in terms of isomorphism or embedding) if the notion were entirely divorced from an ontology of individuals.[19] In this Psillos is very probably correct; however, that bears little relevance here because if the deflationary view I advocate is adopted, the motivation for Ladyman's distinction disappears. Ladyman introduces 'metaphysical' structural realism exactly because of what he takes to be the untenability of the claim that although the world contains unobservables, *only* its structure can be known. However, as we have seen, structural realism as I claim it should be read is not committed to this thesis. It is committed to the thesis that the world's structure is knowable, and is silent on whether or not the definitions of the particulars referred to (as distinct from the equations they appear in) ought to warrant belief. Indeed, as Psillos notes, it is plausible to suppose that the correct attitude to this latter

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17 J. Ladyman, 'What is Structural Realism?' *Studies in History and Philosophy of Science* **29** (1998) 409-24

18 W. Demopoulos and M. Friedman, 'Critical Notice: Bertrand Russell's *The Analysis of Matter: Its Historical Context and Contemporary Interest*,' *Philosophy of Science* **52** (1985) 621-39

19 S. Psillos, 'Is Structural Realism Possible?' *Philosophy of Science Association* **68** (2001) S13-S24, at S22

question will be local and not global. And this is in perfect keeping with the deflationary view I advance here.

While providing a plausible critique of Ladyman's proposals, Psillos's most recent writings[20] still criticize structural realism (including Worrall's version in 'Structural Realism') on the basis that it entails the thesis that *only* structure can be known. Also present is the notion that it adheres to a problematic distinction between structure and nature.[21] Thus, Psillos's recent work is still vulnerable to the criticism I have already provided. However, it is interesting to note that Psillos does allow for the possibility that structural realism might be plausible if it abandoned a thoroughgoing structuralism.[22] It is interesting to note, then, that the sort of position Psillos's recent work acknowledges to be plausible is, in fact, largely consistent with the deflationary approach to structural realism I am advocating in this paper. This is so because the version of structural realism that I am defending has no commitment to a thoroughgoing structuralism. It also denies the need for recourse to a view like Ladyman's.

Structural realism as I characterize it, then, provides a plausible explanation of certain features of theory change. It does not relegate the definition of terms to the realm of ontological speculation about 'substances' as Psillos would have it. Because it is not a thoroughgoing structuralism, i.e. it does not actually claim that we are restricted, in our understanding of nature, to purely ontological hypotheses, it need not preclude valid philosophical speculation and debate about the degree of belief that is warranted of the constituents of current theory. Psillos's first entry in his list of theses to which structural realism is committed should therefore be revised. Recall that the first thesis he identifies is the claim that 'Scientific theories, *at best*, reveal the logical form or structure of the underlying physical reality by means of mathematical structure.'[23] However, my characterization of the view would alter this thesis to the claim that scientific theories reveal the logical form or structure of the underlying physical reality by means of mathematical structure (in the local sense permitted by the deflationary approach). The condional 'at best' causes the trouble for reconciling structural realism with a deflationary view, but Psillos, as we have seen, included the clause based on his

20 'Is Structural Realism Possible?'

21 Cf. 'Is Structural Realism Possible?' S23.

22 'Is Structural Realism Possible?' S22-3

23 'Is Structural Realism the Best?' 20, my emphasis

inaccurate characterization of the nature of the structural realist view. If accurately characterized, nothing prevents structural realism from being integrated as a part of a more comprehensive deflationary approach to the realism question.

IV Conclusion

When structural realism is characterized in the way I have argued it should be, it becomes clear that it can be a valuable philosophical tool for characterizing a large quantity of instances of theory change. The debated Fresnel/Maxwell case, as it turns out, is well accounted for by structural realism. In fact, it can readily augment a more general deflationary approach to the realism question that sanctions a variety of stances which do not call for either equal commitment to all the structures postulated by current theory or belief only in observable content. However, seen from this point of view, structural realism is not exactly the 'best of both worlds.' This would imply that structural realism replaces both traditional realism and anti-realism. However, the view that I advocate allows for different interpretations of the constituents of current theory that permits some constituents to be regarded in a realist light and some in an anti-realist light. The main lesson to be learned from the deflationary approach is that, in fact, the realist, anti-realist, and, if my arguments are correct, the structural realist need not be taken to live in different worlds at all.[24]

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