Title	Structure in action
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Citation	The 2013 Workshop on Causation and Structuralism, Cologne, Germany, 8 February 2013.
Issued Date	2013
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Structure in Action

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February 2013 - do not cite without permission

Abstract

In this paper I consider the options for structuralist approaches that aim to incorporate an account of causation as part of giving a metaphysics of physics. I argue that structuralists are committed to giving an account of causation as part of giving an account of change, especially since prima facie appealing accounts of change and causation, like causal process theory, are incompatible with central structuralist commitments. I sketch out a structuralist account of change in terms of fields as the ontologically fundamental entities, but raise concerns about the ability of structuralists to avoid commitment to particles as causes.

1 Introduction

There are many different philosophical accounts of causation, and there are many different philosophical positions that go by the name of 'structuralism'. If we ask what kind of account of causation a structuralist can give, we need to get clear, on the one hand, on the versions of structuralism we would like to consider, and, on the other hand, about what it is we expect from an account of causation.

In this talk I will be focussing on structuralists who are interested in giving

a *metaphysics of physics*. Structuralists pursuing this goal aim to articulate a metaphysical position compatible with, and perhaps indeed inspired by, fundamental theories in contemporary physics. I will furthermore assume that the structuralists in question see it as part of their structuralist position that 'structures' are in some sense more fundamental than 'objects', although I do not mean to restrict myself just to those structuralists who want to eliminate objects altogether. Finally, I will be looking for a structuralist position that can accommodate causation. Not all structuralists aim to do so—some might prefer an account that explicitly excludes any causal notions.[1] So the structuralism I will be interested in for the purposes of this talk is one that tries to give an account of causation in the context of presenting a metaphysics of physics, while remaining committed to the idea that structures are more fundamental than objects.

One way to give a structuralist account of causation would be to go through all extant views of causation and to opt for the one that offers the best fit between physics and the structuralist commitments. This will not be my strategy in this talk. Instead I will be looking for a more organic way of fitting causation into a structuralist metaphysics. Many different views of causation may be compatible with central structuralist ideas, but I believe that structuralists can do better. Rather than taking on board whatever fits from other views, I want to see whether they might be able to develop a view of causation that is genuinely their own. I hope that this strategy will assuage those structuralists who worry that having to give an account of causation is just an imposition created by bad metaphysics[2] with no proper place in physics or the philosophy of physics.

In section *one* I consider different motivations a structuralist might have for

[1] Compare for example the sympathetic discussion of eliminativism in Ladyman and Ross (2007).

[2] On the notion of 'bad metaphysics', see again Ladyman and Ross (2007).

wanting to give an account of causation, and suggest that the central task for a structuralist account of causation is to give an account of change. In section *two* I articulate what needs to be done to give an account of change, why that might present a challenge for structuralism. In section *three* I consider a mediating strategy for accounts of change and causation in the context of modern physics: causal process theory. I argue that this strategy does not work for the structuralist. In section *four* I offer a purely structuralist response to the problems outlined in section two. I argue that structuralists need to insist on building their account around the idea of *dynamical* structures, but that they have to give up the idea of modeling those structures on processes in the sense of world-lines. In section *five* I argue that even for this genuinely structuralist response, giving causation its due means accepting particles into the ontology, although not as persisting particulars.

2 Why should structuralists care about causation?

A structuralist might have a number of different motivations for wanting to include causation into her view, and depending on the exact motivation, there are different desiderata an account of causation has to fulfill.

Structuralists are often confronted with the charge that on their view, there is no distinction between mathematical and physical structure. While some structuralists endorse this idea, and argue for a purely mathematical structuralism, many others try to find a way of articulating a structuralism that distinguishes between physical and mathematical structures. A structuralist account of causation might offer a means by which to distinguish mathematical from physical structures: physical structures are in some sense causal, mathematical struc-

tures, by contrast, are not.

A structuralist whose main motivation for incorporating causation into her view is the desire to distinguish mathematical and physical structures will be looking for an account of causation that rules out that mathematical entities could have causal attributes, for example by attributing causal powers to physical structures. Mathematical entities don't push or pull; they don't have the power to heat water or to attract metal. While most philosophers would be inclined to agree that mathematical entities are acausal in that sense, the notion of causation at work here is fairly robust. The question is, on the one hand, whether a robust notion of causation has a home in fundamental physics, and on the other, whether sense can be made of the attribution of causal properties to structures. And Michael Esfeld has of course argued that this is possible. (2009)

Other structuralists see *naturalism* as the main reason for giving an account of causation.[3] A naturalistic metaphysics is the attempt to accept into one's ontology only entities 'sanctioned' by science. What it takes for an entity to be sanctioned by science is itself a non-trivial question naturalists need to address, but a fairly standard criterion is that naturalists are committed to all entities that feature irreducibly in scientific explanations. Since there seem to be irreducible causal relations described by sciences other than physics, an account of causation that is only suitable for physics will not be sufficient to account for such irreducible causal relations in other sciences. Accordingly, naturalistically motivated structuralists have rejected the idea of altogether eliminating causation from their account. Instead they are faced with the problem of developing an account of causation that is sufficiently structuralist while being broad enough to cover causation across different science.

[3]This is main motivation for Ladyman and Ross (2007) for rejecting eliminativism about causation.

A third motivation for incorporating causation into a structuralist metaphysics is to give an account of change. Structuralism has been accused of failing to give an account of change, since understanding change, it is alleged, requires objects that undergo change (Chakravartty, 2003). Giving an account of change is tied to causation insofar as giving an account of causation is needed to explain what brings about change. The challenge for the structuralist here is both to give a structuralist substitute for an object based account of what it means to undergo change, as well as giving an account of what brings about change.

Depending on the motivation for giving a structuralist account of causation, the desiderata for such an account will be somewhat different. For example, the problem of causal asymmetry of higher level causal relations plays an important role in the project of reconciling the causal relations of higher level entities with the time-reversible laws of physics, but causal asymmetry need not be the main concern of those trying to distinguish physical from mathematical structure, nor is it obvious that it should be central to a structuralist account of change.

While the different desiderata are not in obvious contradiction with one another, and in some cases may even overlap, trying to fulfill all of them nonetheless sets the bar very high for giving an account of causation in structuralist terms. Having isolated these different motivations, I suggest that it is a good idea to start explicitly from one of them, and to develop an account of causation on that basis. Perhaps that account will do justice to the other motivations as well, but if not, we shouldn't despair. For the rest of the talk I will proceed from the motivation of giving an account of change.

The main reason for this choice is that I think giving such an account is central to the whole structuralist project of providing a metaphysics for modern physics. The description and explanation of change is central to physics, and

is accordingly central to *meta-physics*. Naturalistic closure, by contrast, is an additional aim, which structuralists may or may not adopt. Whether or not the account developed will suffice to distinguish mathematical from physical structure is also a matter I will leave open at this point. Those who wish to draw such a distinction will of course embrace an account of causation that allows them to do so, but even if the account of causation fails to be robust enough to accomplish this goal, they can still try to find a different way of distinguishing physical structure. For the rest of this talk, then, I shall only be concerned with causation insofar as it can contribute to a structuralist account of change.

3 Change as problem for structuralism

The difficulty for structuralists in giving an account of change, say critics of structuralism, is that our ordinary accounts of change depend on objects. In traditional terms, such an account would of course have been given in terms of a substance, which remains self-identical while undergoing various changes in (some of) its properties: changing position, turning blue, and so forth. But even the contemporary debate, carried out between *three-dimensionalists* and *four-dimensionalists* is a debate over whether *persisting particulars* endure or perdure, that is to say, over whether we should say an object persists by being wholly present at different times, or by extending over different times by having different 'temporal parts' at different 'temporal locations'. Whichever of these two accounts of persistence may ultimately be more appealing, it is clear that both aim to offer accounts of what it is for *an object* to persist over time. Since an account of persistence over time is usually taken to be an integral part of any account of change, accounts of change ultimately still seem to depend on objects.

Persistence, however, is only one half of an account of change. The other half is an account of what brings about changes, that is, an account of causation. Here we similarly find that objects seem to play a central role. Traditionally, again, we find substances as causes, as bringing about change.

The majority of contemporary philosophers prefer to see *events* as the relata of the causal relation, but that does not mean purging the account of objects. Events here are typically occurrences like Billy throwing a rock or the shattering of a window, not the puristic intersections of world-lines in special relativity. In other words, events are occurrences some of the constituents of which are objects. That is unsurprising, and not per se objectionable, since the goal of most theories of causation is to analyze our ordinary concept of causation, which of course deals with rather ordinary occurrences, which we in turn do typically understand in terms of ordinary objects.

Structuralists do not aim to offer a specifically structuralist account of *ordinary* notions of causation. Nor should they be concerned to offer a full-blown substitute for an account of the persistence of objects, since objects, after all, are perhaps to be eliminated from the ontology altogether, and in any case are not supposed to be fundamental. The question is, instead: what exactly should structuralists aim to accomplish with an account of change? Given the commitment to giving an adequate metaphysics for physics, it seems clear that a structuralist should develop a model that accounts for change as described by physics.

The main decision for a structuralist will be whether to emulate the persistence based account of 'object oriented metaphysics' by taking structures to be the (relatively) stable relata of causal relations, or whether to opt for a radically different approach, in which causal relations don't *connect* structures, but are themselves a relation in the structure.

In the former case the structuralist account will have a two-tiered structure, explaining on the one hand what it means for a structure to persist, and on the other hand what it means for two or more structures to interact. The two advantages of this strategy are that the structuralist account will match the 'object oriented' account fairly closely, and that it is (accordingly) relatively clear how to go about developing such an account. Possible disadvantages of this strategy are that even if it can be established that structures are capable of playing all the roles required by such a two-tiered account, the motivation for going structuralist might be lost. A structuralist will have shown that her account can match the demands of 'object oriented metaphysics', instead of showing that the demands are misplaced and that a structuralist account is suitable for responding to different, more important demands. A natural place to look for such demands in physics. If it can be shown that physics itself makes demands that make this two-tiered structure unsuitable, structuralists would have a reason to reject the 'object oriented' account, and a motivation for their own, different, strategy.

In the next section I will point out prima facie problems contemporary physics poses for accounts of changed based on persisting particulars. I will discuss a view of causation that takes into account these developments in physics, while retaining the two-tiered structure described above. I argue that this 'mediating' strategy is unsuitable for appropriation by the structuralist. I take this as a motivation to look for a genuinely structuralist alternative, which gives up on the two-tiered structure, in section four.

4 Causal Process Theory—A mediating strategy

Contemporary physics seems to challenge the dichotomy between stable, persisting objects on one side, and interactions among them on the other. While this division fits the relationships described, for example, by Newton's first and second laws respectively, it is not immediately clear what, if anything, corresponds to stable, inertially moving bodies in the different areas of modern physics.

Special Relativity seems to teach us that there is no absolute distinction between temporal and spatial directions, since any such distinction requires the introduction of one of several possible coordinate systems. So what does it mean to say that an object persists, if by persistence we mean its remaining self-same *over time*? Furthermore, bodies are no longer the fundamental entities of physics. Instead we have both particles and fields as causally efficacious entities to countenance. It is unclear, especially taking into account the quantum context in addition to relativity theory, how we should metaphysically conceive of either their persistence or their interactions. Post-Newtonian physics, then, poses a challenge for traditional accounts of persistence, change, and causation.

A mediating strategy is causal process theory. Process theory retains the two-tired structure described above by distinguishing between causal processes on the one hand, and causal interactions on the other. According to a recent version of causal process theory, a causal process is "a world line of an object that possesses a conserved quantity" (Dowe, 2000, 90), and a causal interaction is "an intersection of world lines that involves exchange of a conserved quantity" (Dowe, 2000, 90). Using conserved quantities as the characteristic feature of *causal* processes and interactions is Dowe's particular innovation; it is his attempt at responding to what is perceived to be the greatest difficulty

for a process theory of causation: the ability to distinguish causal processes from 'pseudo' processes. For our purposes more relevant than the distinction between pseudo processes and causal processes (or Dowe's way of drawing the distinction) is the two-partite structure of the account, which is common to all causal process theories. This distinction corresponds roughly to the distinction between changing over time without external influence, and changing through external influence. Distinguishing between internal and external influences commits the causal process theorist to an account of identity over time, as we shall see in more detail below.

Can a structuralist appropriate the process theorist approach in dealing with change and causation? One strategy, let's call it Option A, is to find the structuralism in process theory by taking structure to be what is stable about a process.[4] Since what makes a causal process a *causal* process, is that it must be capable of transmitting something, such a process must be stable, and this stability is to be understood as *structural* stability. The conserved quantities account would then be viewed as just the most recent way of articulating what it means for a process to have a stable structure. A structuralist could try to argue that process theorists give a structuralist account of causation insofar as they explain causal relations in terms of causal processes, and causal processes are defined as structure preserving ones. So structure would appear to play a major role in the account of causation.

There are two problems with this way of viewing process theory as a structuralist account. First of all, it does not address the problem pointed out above, namely that causal processes are nonetheless defined in terms of objects and their properties. What is preserved, in the conserved quantities account, is the property of an object: it has the same conserved quantity. Even if we attempt

[4]See for example Rueger (2006) in the context of developing a process theory, although not with a specifically structuralist agenda.

to give a structuralist analysis of conserved quantities, however, this approach is still one that explains causation ultimately in terms of objects and their properties.

Second, it is unclear what the connection between *structure* preservation and causation is supposed to be. What seems needed is that processes be stable, but why that stability should be a *structural* as a opposed to a qualitative stability, or why we should consider the currently proposed candidates for stability to be structural in any significant sense, is unclear. Indeed, if we look at Russell's original proposal, it is clear that he thinks structure is only one way in which a process can be stable: "Throughout a given causal line, there may always be constancy of quality, constancy of structure, or gradual change in either, but no sudden change of any considerable magnitude" (Russell, 1948, 477). What makes a process (or a causal line) stable, is that changes to it are not sudden, but that criterion by itself does not suffice to conclude that what is preserved in causal processes is structure. More importantly, even if we give a structural characterization of what's being preserved, it is not the fact that what is preserved is *structure* that makes the process causal, but the fact that something is *preserved*. Option A, then, does not appear to be a good strategy for structuralist appropriations of causal process theory.

The second approach, Option B, is more radical. Instead of taking the structural aspect of a process theory to be found in what is preserved or stable in a causal process, the process itself is taken to be the structure. A process, on this option, is a dynamical structure, not something that preserves the structure of something else.

This second approach faces two main obstacles: (a) the reference to objects in the definitions of processes as world lines, and (b) the temptation to decompose a process into a sequence of events. The former is obviously an obstacle, because

it would make objects once again fundamental; the latter is an obstacle because events themselves look like particulars, not structures.[5] Process theorists, and most certainly process theorists who want to be structuralists, need to insist that processes are more fundamental than events. A standard way of doing so is to suggest that events are the intersections of two or more processes. But why should we not go the other way?

Processes and events seem interdefinable.[6] An event is an intersection of two processes, but a process seems to be nothing more than a sequence of events. As Russell puts it: "A 'causal line', as I wish to define the term, is a temporal series of events so related that, given some of them, something can be inferred about the others whatever may be happening elsewhere" (Russell, 1948, 477). Russell's definition is offered in terms of our ability to draw inferences about what happens to other events from some of the events in the series. Events that afford us inferential connections in this way form causal lines. Unless we want to read this in a strictly subjectivist fashion, however, there seems to be a legitimate question: what is it about these series of events that allows us to draw inferences about them? Russell does not offer an answer to that question, and one suspects he doesn't want to do so, but a metaphysical account cannot refuse to answer this question.

The idea that a process can instead be defined not as a series of events but as the world-line of an object, is a natural attempt to answer this question. By defining a process as the world-line of an object, processes can be individuated,

[5]Structuralists might of course attempt to offer a 'structuralist' interpretation of either events or objects in this context. But this does not seem like a promising strategy at this point. After all, re-interpreting apparent particulars like objects and events in terms of structures seemed most promising if we could understand them, in the case of objects, as the stable results of causal processes, and in the case of events, as the intersections of causal processes. So the best structural candidates for doing the reinterpretative work are exactly the ones whose independence from objects and events is under attack.

[6]In a similar way in which space-time worms and temporal parts/stages seem inter definable.

and gerrymandering of processes from just any events is avoided.[7] Which events form a process is defined by which events are part of the world line of a particular object - we know which events to look for because we know which object we are tracking. This means, of course, that the process account here continues to rely on objects, and more importantly, on persisting objects at a crucial point in the account. In talking about the world-line of an object we are talking about the persistence of an object, albeit in a nicely relativistic manner, and it is in doing so that we prioritize the sequence of events over the individual events out of which it is composed. Furthermore, we can say which events get to be part of the same process by first individuating the objects. Without defining processes as word lines of objects, then, a process theory can neither individuate processes, nor prioritize processes over events.

Since building persisting objects into the individuation criteria for processes is clearly unacceptable for the structuralist, a structuralist appropriation of the process account a long the lines of option B also seems fraught with obstacles. But Option B introduced an important departure from previous approaches to causation, which I think should be taken on board by structuralists. A structuralist should think of causal relations as part of the structure she is taking to be fundamental, instead of thinking of structures as relata of an independently characterized causal relation. The key to this is to understand structures as dynamic, but as the argument above suggests, perhaps not as processes in the sense of world lines.

[7] Dowe is especially explicit about this; he in particular rejects time-wise gerrymanders, which commits him to a notion of identity over time independent of causal relations.

5 A genuinely structuralist approach

The world-line, as a generalized trajectory, is still tied to the notion of a persisting object traveling on that trajectory. If structuralists aim to understand change and causality in terms of dynamical structures, they need to give up on the idea of a process in the sense of a world-line as the paradigmatic case of a dynamical structure. A natural alternative are fields.[8] A plausible strategy for structuralists to give a genuinely structuralist approach to change and causation is to show that change and causation in the context field theory are not well understood in the terms offered by metaphysical views that put persisting particulars at the heart of their ontology.

A first point to be established, then, is that fields do not persist. A field is, by definition, a structure extended both in space and time. Since there is no principled difference between spatial and temporal variations in fields, fields cannot be said to endure. Enduring entities are wholly present at different times, whereas they are not wholly present at different locations in space. Endurantists are committed to the idea that there is a difference in temporal change and spatial variation. Fields are not entities for which such a distinction is appropriate.[9]

Should we say that fields perdure, then? A perduring entity is one that has temporal parts at different temporal locations, just as it has different spatial parts at different spatial locations. But it seems odd to say of fields that they have parts. A field is a vector quantity, which can have different strengths and directions at different locations (in the classical theory these locations will be points). But while we can of course distinguish the strength or direction of the field in different regions, it makes little sense to speak of these regions as different parts of the field. Certainly in the classical case we want to distinguish

[8] Structuralists have opted for a field ontology on other occasions, see for example French and Ladyman 2003.

[9] Notice that this does not mean that there are no enduring entities. It just means that fields are not enduring entities.

between a field of certain values present in a region of space(-time) and the region of space(-time) itself. Similarly, different fields can be present within the same region of space-time (e.g. electromagnetic and gravitational fields). It would be odd to say that the two fields share their parts. The difficulty arises because fields are not bound to material carriers. They do not need bodies to inhere in, and our conception of parthood seems deeply bound up with the idea of material bodies. Material bodies that can (in principle) be composed and taken apart, that is to say, that can be moved rigidly and independently from their surroundings. Field theory ultimately calls into question that conception of rigid motion.

If fields cannot be said to have temporal parts because they ultimately don't have parts, they don't perdure in the sense of perdurance theory. As we've seen above, fields also don't endure. Since perdurance and endurance are offered the two ways in which entities might persist, it seems that we should conclude that fields don't persist. A slightly better way of putting this would be to say that fields are dynamical entities to which the notion of persistence does not apply.

In a sense that should not come as a surprise. Persistence is tied to the notion of identity over time, including in particular the case of identity over time in spite of changes in properties. But since in the case of a field, which lacks a 'material basis', it makes no sense to distinguish between changing properties and stable 'underlying' thing, it is unsurprising that persistence doesn't appear to be applicable. Changing field values are not the changing properties of an otherwise self-same entity. They, and the relations among them, are the entity. Since the field values in one location depend on/are influenced by the field values in the vicinity, it makes sense to speak of a field as a structure. Hence it is unsurprising that structuralists have sometimes suggested that the structures they take to be fundamental are in fact fields.

If adopting a field ontology means giving up on persistence for the most fundamental entities, and doing so is what structuralists intended to do, does that mean structuralists cannot give an account of change? I don't think so. Fields may not persist, but they do change. They change not through locomotion on well defined trajectories, or by changing their properties, but by being themselves dynamical structures. Fields are dynamical structures in the following two senses: they can vary spatio-temporally, and they can interact with particles.

Spatio-temporal variation, as we said above, should not be understood as having different parts in different spatial or temporal locations. Fields (can) have different strength and direction at different locations. That much is uncontroversial. The difficult questions for a structuralist, but really for anybody who wants to speak about fields as dynamical structures, is to say how this variation of field values is brought about. That is to say, the crucial challenge in describing fields as dynamical structures is not that fields don't persist, but to explain why there are fields at all, and why their strength and direction can vary.

The second sense in which fields are dynamical structures is that they can interact with particles. One way to think about the interaction of a field with a particle is to think of the particle is traveling 'through' a field on a trajectory. Spatio-temporal variations in the field will affect the particle's trajectory. Thinking of it that way means to assume the field itself as somehow 'given' or present[10], and the particle as a persisting particular on a well-defined trajectory. It is easy to miss that even in this description we are attributing causal powers to the field, that is, we describe it as a dynamical structure in the second sense. Since fields, on this picture, bring about changes to the trajectories of particles by varying spatio-temporally, we can moreover say that fields are dy-

[10]That is, to bracket the worries just raised in the previous paragraph.

namical structures in the second sense, in virtue of being dynamical structures in the first sense. This description gives primary causal powers to the fields: it is because they are spatio-temporally varying structures that we can attribute to them the causal power of changing the trajectory of appropriate particles.[11]

6 Some concerns and refinements

In the previous section I've articulated a genuinely structuralist approach to change and causation in terms of fields as the fundamental physical entity. While this approach can help us to appreciate the distinctive features of a structuralist account, namely the idea that change and causation are to be understood exclusively in terms of dynamical structures without persistence conditions, it also raises some new questions about the relationship between particles and fields.

I've suggested that structuralists should take fields as the fundamental entities, and I have described them as dynamical structures in two senses: as varying over space-time, and as influencing the trajectories of test charges traveling through them. Particles traveling on trajectories are bound to raise two types of objections. On the one hand, purely philosophically, it might be argued that this means that the structuralist account of fields as dynamical structures needs to be supplemented with an account of the persistence of particles after all. On the other hand, from the perspective of physics one might object that we have to give up the idea of particles traveling on well-defined trajectories as soon as we take into account quantum considerations.

It turns out, that the combination of these objections is actually an advantage for the structuralist. For she might agree with the philosophical objection that the (semi-)classical account of field-particle interaction given in the previ-

[11] Ultimately this power resides in the field-quantities: it is because the particle and the field have the appropriate quantities that they can interact. Not all fields interact with all particles.

ous section indeed continues to be committed to persisting particulars in the form of particles traveling on well-defined trajectories. The structuralist should hence be grateful if a reason can be given for discharging that commitment. Quantum considerations seem to offer just such a reason. So instead of feeling battered from two sides, the structuralist should simply endorse the considerations from quantum physics and insist that descriptions of particles traveling through fields on well-defined trajectories are at best a semi-classical approximate model useful in certain circumstances, but not the account from which we should derive our best metaphysics. The structuralist's answer to the philosophical objection is then that our best physics ultimately gives us an independent reason for thinking that persistence has no special role to play in our account of change and causation even if we retain particles as elements of the ontology. Quantum particles are not persisting particulars.

Nonetheless, this victory for the structuralist will come at a cost. Giving up the classical description of particles as persistent particulars means we have to reconsider the classical descriptions of fields as well. In particular, it means giving up the idea that fields are dynamical entities in the second sense in virtue of influencing the trajectories of particles traveling through them.

Classical fields are good candidates for fundamental entities because they are self-sustaining, they don't need a material substratum to 'live in'. That does not mean, however, that they are causally independent as well. Instead, moving charges are sources of fields! In the descriptions of the previous section, we've ignored effects of the traveling particle on the surrounding field as negligible, but once we decide to go in for a full-blown quantum field description, this idealization no longer seems appropriate. Instead it seems we ought to be treating field and particles as being in constant interaction with each other, with neither being causally 'more fundamental'.

This does not sink the structuralist's account of either change or causation, since the most important aspect remains intact: an account of change in contemporary physics will proceed in terms of dynamical structures, not persistent particulars. It does, however, count against structuralist approaches that aim to eliminate particles from the ontology. Contrary to the original criticism, the problem does not arise from the alleged need for objects to account for change, or even for objects as carriers of the causally efficacious properties. Instead the key point is that quantum field theory tells us that particles need fields, and fields need particles to sustain each other causally. Neither is causally active unless they are thought of as being causally interactive, and the interactions take place between particles and fields. It is possible that we will eventually develop a theory that eliminates either particles or fields from that interaction, but as of right now, that's not the kind of theory we have. Quantum field theory suggests that particles and fields do not exist independent of each other because of their ongoing causal interaction. Structuralists rightly warn us against treating the particles in these theories as persisting particulars, but they should conceded that the fields cannot be thought of as dynamical structures independently of the particles either.

7 Conclusion

In this talk I've considered the options for a structuralist account of causation whose main goal is to give a structuralist account of change. I have argued that the challenge to account for change arises from within the structuralist project of giving a metaphysics for physics, and I've shown that structuralists cannot simply adopt existing views like perdurantism or process theory to complete their account. Instead, I've argued, structuralists need to develop their own account of change, starting from fields as the fundamental entity. Fields are

paradigmatic dynamical structures, and hence suited to the task of giving a structuralist account of change. While this gives structuralists a promising way of articulating a genuinely structuralist account of change, however, questions about the causation and fields should lead structuralists to a more cautious stance vis-a-vis the existence of particles.

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