How (Not) to be a Humean Structuralist

A response to Lyre's 'Humean Perspectives on Structural Realism'

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While the idea that the structures of ontic structural realism should be understood as in some sense 'modal' has been referred to many times, comparatively little has been said regarding how exactly that modality should be understood. However, Lyre has recently defended the idea that a Humean interpretation of structures is possible by understanding them to be composed of 'categorical' properties and relations. In this paper I raise some objections to deferring to the notion of categorical properties to articulate a modal interpretation of structures, and gesture towards an alternative means of expressing a Humean form of structuralism.

1 Introduction

The idea that the structures of ontic structural realism are to be understood as in some sense 'modal' has often been gestured at, but how exactly that modality is to be understood has received comparably little by way of discussion. Recently, however, Michael Esfeld and Holger Lyre have both articulated explicitly modal interpretations of structures – though they have very different stances on what they take the modal commitments of structuralism to be. Esfeld for example 'appl[ies] the debate about causal vs. categorical properties in analytic metaphysics to ontic structural realism' in order to develop a non-Humean account of structures, where their non-Humean nature is secured by the fact that the relations comprising them are understood to be irreducibly causal, or *essentially dispositional* (Esfeld (2009), p179). Lyre by

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contrast adopts a view in which the properties and relations that comprise the relevant structures are understood to be *categorical* in nature, and takes it that a Humean perspective on structures results from understanding them in such terms (Lyre (2009)).[1]

While the modal interpretations of structures offered by Esfeld and Lyre are diametrically opposed, the *strategy adopted* to articulate these interpretations is the same in both cases. What is assumed by each author is a modal distinction applying to properties that is familiar from analytic metaphysics – namely that between *essentially dispositional* and *categorical* properties – which is then appealed to in order to ground distinct modal interpretations of the relevant structures.[2] This strategy exactly parallels that which is adopted in (what I will call) the 'canonical' debate over laws of nature, in which Humean and non-Humean interpretations of laws are grounded in opposed modal accounts of the nature of fundamental properties. That such a parallel exists is, of course, in many ways unsurprising, given that laws themselves are often taken to be paradigmatic examples of structures in physics.[3]

While this strategy for articulating modality may seem inevitable and natural, I want to argue here that it is nonetheless problematic for structuralists to adopt it. Ontic structuralism is after all a resolutely *naturalistic* thesis, and one that ultimately aims to give an account of the fundamental nature of reality; as such, and as I will argue, it is entirely unclear that structuralists can blithely appeal to a modal conception of properties that has been incubated in the context of analytic metaphysics, given that the latter is often charged with being wedded to *too classical* a picture of reality to be of service in fundamental regimes. My objections will be directed in this instance toward the uncritical invocation of, in particular, *categorical* properties in the context of fundamental physics, and thus upon Lyre's account of modality in structuralism that is predicated upon it. I stress, however, that in so doing I am *not* thereby defending the rival non-Humean account, such as that offered by Esfeld: since I am suspicious not just of the notion of categorical properties, but of the essentially dispositional / categorical distinction itself, for me it is a case of 'a curse on both your houses' insofar as the debate over modality is constructed upon it.

In what follows, I will focus on the fundamental *kind* properties, and my argument will proceed in two stages. I will argue that

(i) The modal metaphysics standardly associated with categorical properties assumes an account of natural law that not appropriate for elucidating fundamental properties; and

[1] As Lyre writes, 'A proper Humean perspective on structural realism is to demand categorical structures and to dismiss mysterious modalities' (*ibid.*, p10).

[2] I will subsume relations under the term 'properties'.

[3] One need think only of the structuralist discussions of Fresnel's and Maxwell's equations.

(ii) If we move to a more realistic account of fundamental laws, and take the QM formalism seriously, it isn't clear that there is any place for categorical properties in our metaphysics – at least not as standardly conceived.[4]

If we want to articulate a Humean version of structuralism, then, I think we should try to find another strategy that does not appeal to the concept of categorical properties, and I will hint at the shape that such a strategy might take at the end. For now, however, I will outline how I understand the canonical account of laws, properties and modality in which the notion of categorical properties was developed. Once that is in place, I will be able to articulate some of the problems that I perceive in the act of appealing, in the fundamental physics context, to categorical properties so conceived.

2 The canonical account of laws, properties and modality

Painting things in as broad brushstrokes as possible, there are two categories of modal accounts of laws. On the one hand, we have *non-Humean* accounts in which laws are taken to consist of metaphysically necessary connections between properties. In the contemporary literature, such accounts are associated with authors such as Bird and Ellis (see e.g. Bird (2007), Ellis (2001)). On the other hand, we have *Humean* accounts in which laws consist of metaphysically contingent connections between properties. Such accounts are primarily associated at present with authors such as Armstrong and Loewer (see e.g. Armstrong (1997), Loewer (1996)).[5]

Each of these modal accounts of laws – just as with Esfeld's and Lyre's accounts of structures – is typically *grounded* in a prior modal conception of properties. Non-Humeans about laws typically assume an account of fundamental properties according to which they are 'essentially dispositional'. Since part of what it is to be an essentially dispositional property is to *imply* instances of laws, on this view a given species of fundamental particle, defined by a given set of fundamental properties, can act in accordance with *one and only one* law across different possible worlds. It is thus this modal conception of properties that non-Humeans typically take to account for the fact that the laws are metaphysically necessary. By contrast, Humeans reject this view of fundamental physical properties, and as such also the idea that the kinds that instantiate such properties bring in their wake a unique law. They rather endorse an opposing

[4]Whether there is a different but sufficiently analogical way of understanding categorical properties that does not fall victim to the objections I raise is an interesting question, but not something I can discuss here.

[5]Since I am drawing the distinction between the two positions in terms of Hume's dictum and not in terms of primitive modality, I (like Bird) place Armstrong's analysis in the Humean category.

view of properties in which they are deemed 'categorical' in nature, and it is this categorical conception of properties that is taken to undewrite the idea that a given kind of particle could behave differently.

However, and while what exactly is involved in the concept of an essentially dispositional property has been discussed at length in many places, I think we have to agree with Mumford when he says that 'it is quite difficult to find, anywhere in the literature, a specification of what exactly is intended by "categorical property"' (Mumford (1998), p75). And of course, without *some* such specification the precise connection between categorical properties and the contingentist interpretation of laws remains murky. One can, however, find a variety of strategies that are used to at least gesture at what is intended by this designation. One finds categorical properties characterized, for example,

(i) in *metaphorical* terms, as those that don't 'look outward to interactions', or as those properties that don't 'point beyond' themselves; those that are 'self-contained... keeping themselves to themselves' (Armstrong *op. cit.*, p69; p80); or alternatively

(ii) in explicitly *nomological* terms, as those properties that are 'free of nomic commitments' (Carroll (1994), p8), or as those that do not 'necessarily involve laws' (Loewer *op. cit.*, p200); or sometimes

(iii) in *spatiotemporal* terms, namely as those properties such that 'their instantiation has no metaphysical implications concerning the instantiation of fundamental properties elsewhere and elsewhen' (Loewer *op. cit.*, p177).

There thus seem to be a number of ways of approaching what is meant by a categorical property. Greater variety does not equate with greater clarity, however, and it would be nice if what is meant by 'categorical' in this context could be sharpened up. A strategy frequently adopted to convey more precisely what it is that is meant is that of simply *conveying by example* the implications of such properties for the laws of nature. So for instance, it is often cited that on this view charged particles are not bound to obey Coulomb's law, and in particular, that 'negative charges might have been disposed to repel positive charges, or some other relation may have held between them' (Bird *op. cit.*, p68). Thus part of what is meant by calling charge categorical is that

$$F(x,y) = +C\frac{q(x)q(y)}{r^2(x,y)}$$

– Coulomb's law with a sign flip – represents a possible law. Similarly, it has been said that if charge is categorical then 'the contribution of distance might have been such that an inverse

cube law held' instead of the Coulombic inverse square, so that

$$F(x,y) = -C\frac{q(x)q(y)}{r^3(x,y)};$$

is also taken to represent a possible law on this view (Armstrong (2005), p313).[6]

While the specific examples offered of alternative laws are typically rather conservative in how they differ from actual laws – consisting in these cases just of a sign flip and a unit increase of power respectively – such discussions nonetheless tend to be silent on what *principles govern* how the actual laws may be tinkered with so as to generate acceptable other-worldly alternatives. Without some such statement, the exact relationship between categorical properties and possible variation in laws – and hence the concept of categorical properties itself – can only remain unclear. Perhaps we should take it – since such properties are regarded as 'free of nomic commitments' – that it simply goes without saying that there *are* no such principles (or at least no non-trivial ones). But if *that* is the case, then we can improve upon this strategy of conveying by example what is meant by 'categorical' by moving to a more general – and thus more definitive – characterization in the following way.

Recall that the example that we just looked at was that of Coulomb's law. This law is a paradigmatic example of a *classical* law, and of a *functional* law. That is, Coulomb's law is a law of the form

$$a(x) = f(b(x), c(y), d(x,y))$$

where $a(x)$, $b(x)$, $c(y)$ and $d(x,y)$ are real- (or real vector-) valued functions representing the determinable physical properties A B, C and the relation D, and f is some *functional* (that is, a function of functions). Thus note that the conception of laws that is in play in the contemporary debate on laws of nature is *not* the old $\forall x(Fx \rightarrow Gx)$-type formulation that was central to earlier discussions. The stated reason that Armstrong provides for this move away from the older representation is that

> The laws that have the best present claim to be fundamental are laws that link together certain classes of universals, in particular, certain determinate quantities falling under a common determinable, in some mathematical relation. They are functional laws... Only if we can give some plausible account of functional laws... do we have a theory of lawhood that can be taken really seriously (Armstrong (1993), p242).

[6] Armstrong's example in fact concerns mass and the law of gravity, but the claims are perfectly analogous.

Assuming such an account of fundamental laws, then, we can better formalize what is at issue between the two camps in the canonical debate over their modal status. Suppose first of all that a fundamental law, say an actual fundamental law, is given by

$$a(x) = f(b(x), c(y), d(x, y))$$

for some specific properties A to D. Non-Humeans will then hold that, since the fundamental properties are *essentially dispositional*, then

$$\neg \diamond a(x) \neq f(b(x), c(y), d(x, y)),$$

and in particular that

$$\neg \diamond a(x) = f'(b(x), c(y), d(x, y)),$$

where $f' \neq f$. Thus in this context in which laws are conceived of in functional terms, it is not merely the *properties* to which a given property is related to that must be held fixed across possible worlds, but also the *way in which* it is so related, where that 'way' is expressed in terms of a functional connection between properties. By contrast, Humeans will hold that

$$\diamond a(x) \neq f(b(x), c(y), d(x, y)),$$

and in particular that

$$\diamond a(x) = f'(b(x), c(y), d(x, y)).$$

As mooted above, if properties are categorical then it seems there should be no non-trivial constraints on the form of the laws that any such properties feature in, and hence no non-trivial constraints on the choice of f'.[7] But then another and more perspicuous way to characterize a categorical property is as one that is 'independent of its nomic role' (Mumford (2004), p150), where that role is *defined* by (i) the functional form of the law and (ii) the identities of the

[7] By 'trivial' constraints on the functional form of laws that a categorical property A can participate in, I have in mind general conditions such as (i) there is no A-dependence on the right-hand side that cancels the occurence of A on the left (as in $a = f(b, c) + a$), or (ii) the form of the equation does not make it inapplicable to some of the determinates associated with the determinable (as in $a = 2$), etc.

properties to which the property is functionally related. That, I take it, may be regarded as the sought-for precisification of what is meant by 'categorical property'.

That completes my outline of the canonical debate over the modal status of the laws of nature, as I understand it. What is assumed first of all is a fundamental modal distinction between properties that sorts them into 'categorical' and 'essentially dispositional' properties – where I take the former to be most perspicuously defined as above – and that modal distinction between properties is used to ground a correponding modal distinction between laws. The laws of principal interest are the *fundamental* laws, where these are assumed to have a functional structure. But when the terms of the debate are stated in that way, it becomes immediately evident that there is a very basic problem afoot. That problem is that this debate over laws in analytic metaphysics purports to describe fundamental laws and properties, and thus capture the metaphysics of fundamental physics; *but fundamental physics properties do not obey functional laws*![8] The reason for this, of course, is that fundamental properties and their laws must be understood within the framework of quantum theory, and quantum-theoretic laws are not – and cannot be – of functional form. But since categorical properties have been *defined* in terms of the relationship they bear to functional laws, we need to consider whether any fundamental property can properly be regarded as such when the latter are out of the picture.[9] Let me therefore now consider whether any fundamental properties may be regarded as categorical in the context of quantum theory, and thus whether appeals to the notion of categorical properties may still be made in that context to ground a Humean interpretation of laws and other structures. As above, I will continue to focus on the fundamental kind properties.[10]

3 Laws and Properties after Quantum Mechanics

While ideally I would directly discuss laws in quantum field theory, I will focus just on the representation of laws in quantum particle mechanics and recount only their basic features.[11]

[8] Or, if we count charge as a fundamental property (which is controversial), at least not in its most 'fundamental guise'.

[9] Since essentially dispositional properties are characterized in terms of their entailment of such laws, analogous problems will apply to them.

[10] Since state-dependent properties are typically taken to be possessed only *conditionally upon measurement*, it is already clear that it will be difficult to maintain that *they* are categorical.

[11] A referee has rightly pointed out that it may not be appropriate to argue for metaphysical conclusions by focusing only on the textbook formalism, as I do here, without taking into account the different interpretations of that formalism. In particular, they argue that if one does not accept that the Hamiltonian corresponds to a fundamental local beable, or that commutation relations are a guide to the fundamental ontology of physics, then one can understand the Hamiltonian as a mere compendium of correlations between events involving

The nearest thing that we have in quantum particle mechanics to the functional template for laws in classical physics is of course the Schrodinger equation:

$$i\hbar\frac{\partial|\psi\rangle}{\partial t} = H|\psi\rangle.$$

Expressed a little more fully, laws of the Schrodinger form are statements

$$i\hbar\frac{\partial|\psi(n_i)\rangle}{\partial t} = H_\alpha|\psi(n_i)\rangle,$$

where H_α denotes a specific Hamiltonian and the n_i denote the properties that identify the kind, or kinds, of particle involved.[12] These Hamiltonians describe both how a single particle's states evolve through its Hilbert space, and also contain all the information about a particle's *interactions* with other systems. For example, the quantity

$$\langle(n, \pi^+)|H_S|(p, \pi^-)\rangle$$

yields the probability that two different particle kinds, a negative pion and a proton, will interact through the strong interaction to produce a positive pion and a neutron.

These facts are of course utterly elementary, but they have immediate and non-trivial implications on whether the fundamental kind properties may be properly deemed categorical. Suppose, for example, that we have particle kind defined by a set of determinate properties $\{n_i\}$ acting in accordance with a law of the above form. Talk of a given kind of particle evolving in time presupposes that the set of properties defining that kind are preserved through time, and hence are conserved by the corresponding Hamiltonian. Within the formalism of quantum mechanics, then, the kind structure of a given world is defined in terms of those properties whose operators *commute* with at least one Hamiltonian operating in that world. Thus to

categorical properties understood in the third, spatiotemporal sense in the list above. However, even *if* that is the case, I do not think that it undermines the present concerns. For one thing, it remains that owing to the different formal concepts of laws and their relationships to properties, the first two conceptions of categorical properties listed above – conceptions which are (implicitly or explicitly) expressed in nomological terms – cannot but come under pressure by the considerations adduced here; since the topic of this paper is simply that one cannot uncritically export the concept of 'categorical properties that was developed in a classical ('functional law') framework into the current context, the mere fact that *some* renderings of such properties are ruled out is enough to make the point. Secondly, however, Lyre is trying to develop a specifically structuralist form of Humeanism, in which commutation relations – especially those involved in the definition of symmetry structures – emphatically *are* regarded as the fundamental ontology (see Lyre *op. cit.* p2, p11), though not as 'local' but as 'global' beables; *ibid.* p11). Thus these formal considerations most certainly *are* sufficient to generate problems, for this variant of Humeanism at the very least.

[12]Some state-dependent variables x_i should also be included in the characterization of the state, but my focus here is just on kind properties.

claim that any such world contains a kind property n_i requires us commit to there being a law in that world involving a Hamiltonian H_α such that $[H_\alpha, N_i] = 0$, where N_i is the operator corresponding to n_i.[13]

Talk of kind properties in quantum mechanics thus brings in its train the demand that (at least some of) the Hamiltonians operating in a world in which the relevant kinds exist have certain structural features – that is, that they satisfy commutation relations with the operators corresponding to those kinds. This demand, however, represents a *non-trivial constraint* on the structure of those Hamiltonians, and hence on the form of the laws governing those kinds – non-trivial in the sense that it can fail.[14] But we already saw that in the canonical account, this was something that categorical properties *did not do*. In that account, a categorical property was one that was 'independent of its nomic role', and that seemed to imply that there were no (non-trivial) constraints on the *mathematical form* – in that case, the functional form – of the laws that particles with that property could partake in.

We can thus already see that there is a difficulty with blithely importing the concept of categorical properties – a concept that was incubated in analytic metaphysics against a background of classical physics – into the metaphysics of fundamental physics. This difficulty is on account of the constraints imposed by the commutation requirements on the laws in any world containing a given kind structure. Now, to see just how non-trivial commutation constraints can be, one need only consider the impact that *symmetries* can have on any realistic discussion of nomological modality. To say that a law in quantum mechanics possesses a symmetry is to say that there is a set of operators U_i such that (i) the U_i form a group (in the mathematical sense) and (ii) for all U_i, $[H, U_i] = 0$, where H is the Hamiltonian corresponding to that law. The presence of a symmetry has important consequences for the solutions of the Schrodinger equation (here presented in time-independent form), namely that

$$H_\alpha \psi(n_i) = E\psi(n_i) \Rightarrow H_\alpha(\psi(n_i')) = E\psi(n_i'),$$

where the n_i again represent a set of determinate properties defining some kind, and the n_j a different set of determinate properties *but of the same determinables* as those that define the first. Thus where there are symmetries of the laws, there are *families of particles* that obey

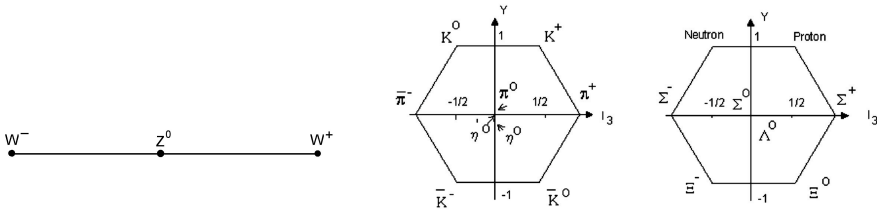
[13] Of course, analogous considerations apply in classical Hamiltonian mechanics as well; so much the worse, in my opinion, for the discussion of modality in analytic metaphysics. Nonetheless, some of the considerations I adduce below are intrinsically quantum mechanical.

[14] For example, the parity operator – against all expectation – was found not to commute with the weak-interaction Hamiltonian. It is nonetheless still used as a classificatory device since it is conserved by other interactions.

those laws with the same energy (hence mass), but different *determinate* values of the same *determinable* properties. Such of families of particles are called 'multiplets'.

As it turns out, the actual laws of physics themselves possess a great deal of symmetry: we have, for example, the SU(2)⊗U(1) symmetry of the electroweak interaction, and the SU(3) symmetry of the strong interaction. That of course means that the particles that populate this world themselves fall into such multiplets. We have for example in Figure (a) the triplet of the weak bosons, corresponding to the 3 representation of the SU(2) symmetry, and in (b) some of the hadrons comprising SU(3) multiplets (the gluons do so likewise).

Figure 1: Actual Particle Multiplets



(a) SU(2) Triplet of Weak Bosons (b) SU(3) Octets of Hadrons

These diagrams represent elegant facts about the fundamental structure of the actual world, but their principal relevance for topic at hand may be seen once one recalls that debates over the modal status of laws are often framed in terms of *duplicates*. We know that non-Humeans hold that otherwordly duplicates of actual particles cannot act in accordance with different laws; as Bird puts it, 'If the particles and fields are the same in the two worlds then they instantiate the same [essentially dispositional properties] and thus give rise to identical laws' (Bird (2007), p84). Humeans of course deny this, holding that otherworldly duplicates of actual particles may accord with different laws (see e.g. Lewis (1986), p163) – and as I have argued, seem to be committed, through their commitment to categorical properties, to their being subject to *arbitarily* different laws. What, then, is the situation here? Can otherworldly duplicates of the actual particles, which as we know occur in *multiplets*, obey arbitrarily different laws?

The answer to this question is a clear and resounding *no*. A little more technically, what the above diagrams represent are *weight diagrams* of the algebras corresponding to the relevant symmetry. But it is easy to show that each such weight diagram corresponds to *one and only one algebra*. What that informs us of in turn is that, wherever in possibility space duplicates of thse actual particles are instantiated, the laws that hold there *must possess the symmetry of the laws of the actual world*. But that represents a *hugely* informative and non-trivial constraint on the laws that any such set of duplicates can accord with. Indeed, one often hears particle

physicists recite the adage that 'symmetries dictate laws': to the extent that that is correct, then it follows that duplicates of actual particles must obey a *unique* law wherever it is that they are instantiated in possibility space.[15] Such a view of laws as metaphysically necessary is of course associated in the canonical picture with the non-Humean view – a view that in turn is based on the rejection of categorical properties. How, then, can one possibly maintain in particle physics a view of the fundamental properties as 'free of nomic commitments', and a corresponding Humean stance toward laws?

Before expanding on that question, I want to take a brief segway to raise a point that gestures, in my mind, to just how radically the debate over nomological modality may have to change if it is to be appropriately reflective of realistic fundamental physics. As just pointed out, considerations of the bearing of the mathematics of symmetry on the question of how duplicates of actual particles can behave led us to something close to the metaphysical necessity traditionally associated with the non-Humean camp; *how* close will be a function of how seriously we take the (problematic) adage that 'symmetries dictate laws'. In the canonical account, that uniqueness was grounded in a prior assumption about modal nature of properties – namely, that they are 'essentially dispositional'; *here*, however, the restrictions on the laws that any given set of particles may accord with *was derived just through the mathematics of symmetry*, applied in the QM framework. But then what exactly the *conflict* with Humeanism consists in is not clear, since Humeans – while suspicious of general metaphysical necessities – are of course perfectly happy to sanction *mathematico-logical* necessities, and hence presumably necessities such as these. What we thus seem to be contemplating is at least the *coherence* of a view in which a broadly Humean metaphysics may be combined with a view of laws as metaphysically necessary, since the latter issued just from the relevant mathematics applied against the backdrop of a quantum representation of laws. Since there is simply no analogue of this in the canonical debate over nomological modality, that in turn suggests that its basic terms may have to be radically revised if it is to be relevant to contemporary fundamental physics – revisions that may extend so far as to undermine the basic Humean–non-Humean dichotomy that defines the basic structure of such debates. And that in turn, of course, should make us yet more suspicious about Lyre's (and Esfeld's) strategy of borrowing concepts developed within that debate to articulate a modal metaphysics for structuralism.

[15] Such a claim is often made in the context of gauge symmetries.

4 Conclusion

To finish, then, let me review the impact of the above considerations on the view, deferred to by Lyre, that the fundamental properties are categorical. We have seen that the attribution of kind properties post quantum mechanics brings in its wake non-trivial – and sometimes *highly* non-trivial – constraints on the form of laws. May we thus regard the fundamental kind properties as being categorical in nature? In other words, and going back to list above, may we consider the fundamental kind properties

- As properties that don't 'look outward' to interactions? The answer is that *it doesn't seem so,* since constraints on Hamiltonians are *ipso facto* constraints on interactions.
- As properties that are 'free of nomic commitments'? Again, *it doesn't seem so,* since one is commited within this framework to the satisfaction of relevant (and non-trivial) commutation relations wherever one defines a kind structure.
- As properties 'whose instantiation has no metaphysical implications concerning the instantiation of fundamental properties elsewhere and elsewhen'? Again, *it doesn't seem so*. It is after all standard practice to represent laws as *global* entities, as properties of worlds themselves: the constraints on the laws implied by the instantiation of a kind of particle in that world – however non-localized, short of being *globally* instantiated, that particle may be – are therefore implications for parts of spacetime that it does not inhabit.

What I hope this all this has shown is that if we want to articulate a Humean metaphysics of fundamental physics – at least if we take the formalism seriously – then we cannot simply defer to the notion of categorical properties in order to do so. As I have hinted, however, I think that the problems with the typical metaphysical discussions of laws, properties and modality are more general, and go deeper, than any specific problem with the notion of categorical properties *per se*. But since I suspect that it may be a lack of attention to the *mathematics* of physics that lies the root of many of these problems, and since a large part of structuralism has consisted of trying to better integrate the mathematics of physics with its metaphysics, perhaps a close study of the modal commitments of structuralism is *exactly the right place to start* if we want to move beyond the traditional debates. Thus while I believe that the work of Lyre, and Esfeld, is flawed as it stands, it may turn out to be a highly valuable springboard for a more physically engaged study of naturalistic modal metaphysics.

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