Advanced Philosophy of Physics: The Philosophy of Symmetries

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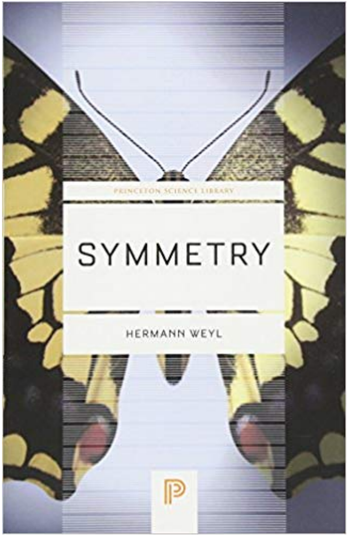
MT20-W1

The plan

- W1: The philosophy of symmetries
- W2: The hole argument
- W3: General covariance and background independence
- W4: The dynamical approach to spacetime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LAWS AND SYMMETRY

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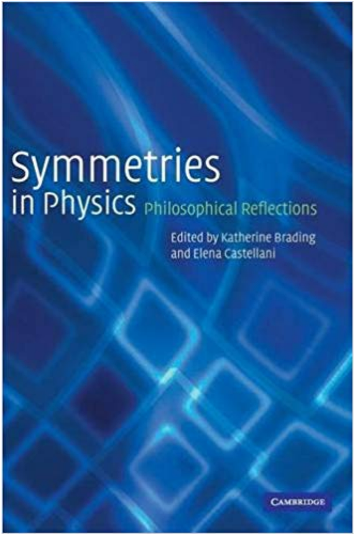
Symmetries
in Physics
Philosophical Reflections
Edited by Katherine Brading
and Elena Castellani
CAMBRIDGE

“Symmetries in physics are a guide to reality.” (Dasgupta, 2016)

Today

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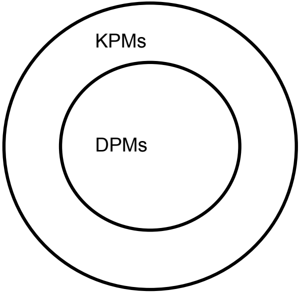
- In Quine's terminology, DPMs pick out a theory's *ideology*.
- A theory's DPMs therefore form a subclass of a theory's KPMs. Sometimes, a theory's DPMs are known as its *solutions*.

Kinematically and dynamically possible models



Interpretation

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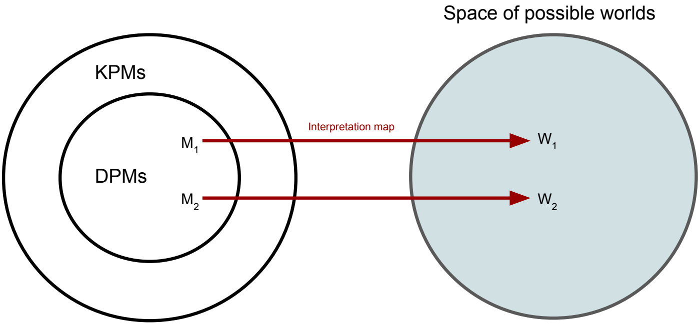

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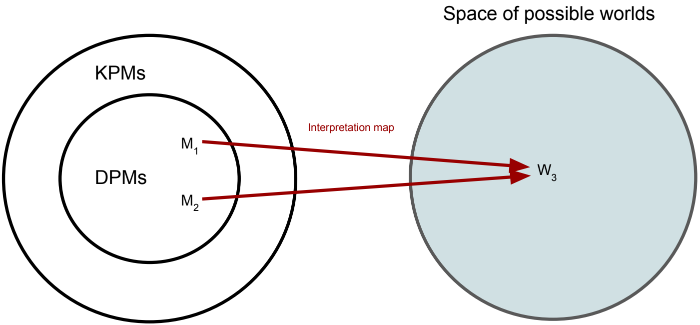

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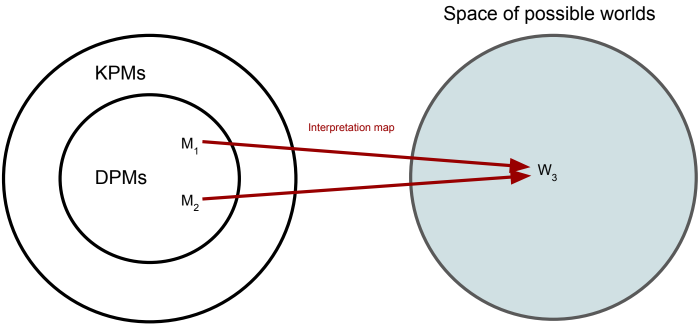

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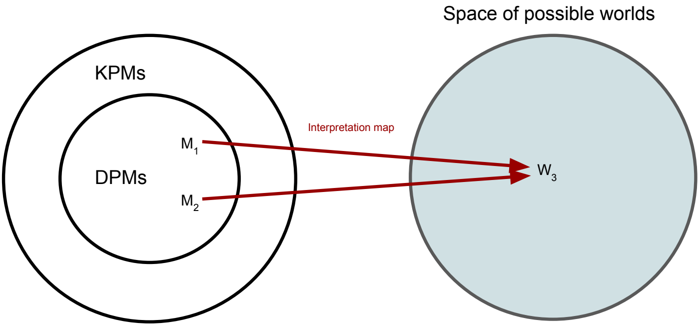

- Question: When is this the case?
- Tentative answer: In the presence of *symmetries*.

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1. What *is* a symmetry transformation?
2. Should symmetry-related solutions of a given theory *invariably* be interpreted as representing the same physical state of affairs?
3. *How* do we articulate that putative common ontology of symmetry-related models?

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Belot (2013) notes that the following two answers to, respectively, the first and second questions, are relatively widespread in the philosophical literature:

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But the combination of D1 and D2 leads to catastrophe!

...So something has gone wrong with the orthodoxy.

Today's project

1. What *is* a symmetry transformation?
2. Should symmetry-related solutions of a given theory *invariably* be interpreted as representing the same physical state of affairs?
3. *How* do we articulate that putative common ontology of symmetry-related models?

We're going to work though the above questions in turn, and try to give more nuanced answers, which (hopefully!) avoid Belot's catastrophe.

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Two phases of the interpretative process

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- In the **first phase** of the interpretative process, a model's *empirical* content is fixed: we establish how a world would look, according to that model.
- In the **second phase** of the interpretative process, a model's *physical* content is fixed: we establish the ontology of the world, according to that model.

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- Regardless of how one *defines* symmetries (more on which later), it is the symmetries which relate *empirically equivalent* solutions of a given theory which are involved in symmetry-to-reality based reasoning.
- Any two empirically equivalent solutions should have the structure which varies between them excised—since this structure is *ex hypothesi* undetectable, and should therefore, given Occam's razor, be eliminated.

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3. Constant shifts of the gravitational/electrostatic potential.

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- **Ontic approaches** “define a symmetry of a law to be a function that preserves the law and also preserves ... [salient physical] features F” (Dasgupta, p. 862).
- **Epistemic approaches** define a symmetry such that “given any set of laws, any two situations related by a symmetry of those laws are observationally equivalent” (Dasgupta, p. 866).

Dasgupta on formal definitions of symmetries

The central problem raised by Dasgupta against formal approaches to symmetries is as follows. Any such definition

> *... must imply that given any set of laws, any two systems related by a symmetry of those laws will be observationally equivalent. Any it is (to put it mildly) extremely hard to see how any purely formal definition could have this consequence.* (Dasgupta, p. 861)

Responses

1. Why assume that all symmetry-related models must be empirically equivalent? In other words: why assume that all symmetries must be involved in symmetry-to-reality based reasoning?

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2. Who said that establishing the observational equivalence of models was easy?

Ontic definitions

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- Examples include dynamical symmetries, Lagrangian symmetries, etc.

Dasgupta on ontic definitions of symmetries

Dasgupta's central problem with ontic definitions is what he dubs the 'problem of inferential circularity':

> *The objection is that they get the order of justification backwards: we often use premises about symmetries in order to work out which physical features fix the data, so we cannot at the same time define symmetries to be those operations that preserve features that fix the data.* (Dasgupta 2016, p. 865)

Responses

1. Not all ontic definitions need be involved in symmetry-to-reality based reasoning (only the ones which preserve the observational data).
2. We don't fix *all* the physical quantities when we offer an ontic definition—just some. So it's not clear that the problem of inferential circularity is damning.

Dasgupta on epistemic definitions of symmetries

In light of the (apparent) problems for formal and ontic definitions, Dasgupta proposes that we should embrace an *epistemic* approach to symmetries: symmetries *just are* transformations between empirically equivalent solutions.

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1. Isn't this defining ourselves out of a problem?
2. The approach is not consonant with physical practice.
3. Why insist that *all* symmetries have to be involved in symmetry-to-reality based reasoning?
4. Doesn't this make the notion of a symmetry redundant as a tool for metaphysical theorising about scientific theories, in the sense that the approach reduces the notion of a symmetry to an Occamist norm?

Today

A normative question

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Should symmetry-related solutions be interpreted *ab initio* as being physically equivalent? (Møller-Nielsen 2017)

Of course, this isn't to say that there is no value to reformulating a theory's formalism in such a way that the surplus structure is made manifest, so that we can move to a formalism in which it is expunged entirely. Such a presentation lets us see what it is we are committed to by our (qualified) realism about the theory; if we want to know the answers to specific questions about the nature of a theory's ontology and ideology, then this is invaluable. ... But if we lack the mathematical tools to do so, then I maintain that there is nothing wrong with recognising that one's realism will only extend to structures that are invariant under the symmetries—whatever those may turn out to be. (Dewar 2015, pp. 326-7)

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I argue, contrary to current orthodoxy, that the variance of a quantity under a theory's symmetries is not a sufficient basis for interpreting that theory as being uncommitted to the reality of that quantity. Rather, I argue, the variance of a quantity under symmetries only ever serves as a motivation to refrain from any commitment to the quantity in question. (Møller-Nielsen 2017, p. 1253)

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- On the **interpretational approach** (Dewar), one may regard symmetry-related models *ab initio* as being physically equivalent.
- On the **motivational approach** (Møller-Nielsen), symmetry-related models may *only* be regarded as being physically equivalent once one has to hand a perspicuous explication of their common ontology.

Perspicuous explication

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Møller-Nielsen: We can only declare these shifted models to represent the same physical state of affairs once we've done the metaphysical hard graft of figuring out what that physical state of affairs *actually is*.

Interpretation/motivation and shifts

> *... [W]e can draw the conclusion of the inference [*viz.*, that shifted solutions should be regarded as physically equivalent] only when we have the alternative theory in hand and have shown that all else is equal. This explains why it was rational for Newton to believe in absolute velocity even though he knew that it was variant ... and undetectable. The reason this was rational for him was that he had no good alternative theory to hand. He had good reason (his bucket argument) to think that relationalism was not empirically adequate. And relationalism was the only alternative view he knew of (he was not aware of Galilean space-time structures in which there is a well-defined feature of absolute acceleration ... but no absolute velocity). So for Newton, all else was not equal and he was rational to believe in absolute velocity.* (Dasgupta 2016, p. 854)

Two challenges for the interpretational approach

1. How are we to identify the common structure associated with symmetry-related models—and have we any reason to think that such structure is always there to be found?
2. Even supposing that such structure can be found, does it invariably admit of a coherent physical interpretation?

Today

Theories and interpretation

Further preliminaries

What is a symmetry?

The normative import of symmetries

Articulating common ontology

Conclusions

An interpretative question

How are we to articulate the common ontology of symmetry-related solutions?

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How are we to articulate the common ontology of symmetry-related solutions?

(Note that this is distinct from our previous, normative question.)

Dewar on this issue

It is often claimed that the symmetries of a theory reveal "surplus structure": structure which, in some sense, the theory could do without. For example, the boost symmetry of Newtonian mechanics indicates the superfluousness of absolute velocities; the gauge symmetry of electromagnetism reveals the superfluousness of absolute potentials; and so on and so forth. Moreover, it is widely held that if this is the case, then some modification of one's theory is appropriate, so as to make explicit what structure is not surplus (e.g. the replacement of Newtonian by Galilean spacetime, in response to the boost symmetry of Newtonian mechanics). ... I compare and contrast two ways of making such a modification. The first is to replace the theory by (what I shall call) a reduced theory: a theory that deals only in quantities which are invariant under the relevant symmetry. The second is to replace the theory by (what I shall call) a sophisticated theory: a theory in which models related by a symmetry are isomorphic. (Dewar 2019, pp. 485-6)

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Reduction and sophistication

- **Reduction**: “the idea is that we (i) identify some collection of invariants of the original theory; (ii) specify a theory in terms of those invariants; and (iii) show that the new theory captures all the symmetry-invariant content of the old theory.” (Dewar 2019, pp. 492-3)

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- **Sophistication**: “the idea is that we need not insist on finding a theory whose models are invariant under the application of the symmetry transformation ... the proposal is that we instead look for a theory such that [symmetry-related models of the original theory] M and N give rise to distinct but isomorphic models.” (Dewar 2019, p. 498)

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- **Traditional sophistication**: The sophisticated substantivalist thesis we have seen before. (A concrete, transparent, metaphysical thesis.)
- **Radical sophistication**: The claim that symmetry-related solutions should be interpreted ‘as if’ they are isomorphic. (In general, no accompanying metaphysical thesis.)

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- **Internal sophistication** is distinct, and is not problematic in the same way: rather, the concern here is that it is just a version of reduction.

I’ll focus on external sophistication today, but for further discussion of the external/internal distinction, see (Jacobs 2020) and (Martens & Read 2020).

Back to external sophistication

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Sider on external sophistication

> *There may be no way to say what is "really" going on; maybe every good model has artifacts. It's ok to just say: this model does a good job of representing the phenomenon, but certain features of the model are artifacts. Moreover, for any model, we can say which features of the model are genuinely representational and which are artifacts. There is no need to provide some privileged, artifact-free description from which we can recover this information.* (Sider 2020, p. 193)

Dewar’s views

- Dewar *accepts* our previously-articulated problems for the interpretational approach:

  > *it is highly non-trivial to find such a reduced theory—or even to demonstrate with confidence that such a theory could exist.* (Dewar 2019, p. 495).

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- However, he contends that this is only a problem for the interpretational approach *combined with reduction*—and that the interpretational approach may be saved when combined instead with sophistication.
- Thus, Dewar maintains that symmetry-related solutions may *invariably* be regarded as being physically equivalent, and that the ontology of symmetry-related solutions can *invariably* be articulated via (radical) sophistication.

Two orthogonal debates

1. Interpretation + reduction (Caulton 2014)
2. Interpretation + sophistication (Dewar 2019)
3. Motivation + reduction (Dasgupta 2016)
4. Motivation + sophistication (???)
5. Some more complicated cocktail (Møller-Nielsen 2017)

Problems for sophistication

Let’s turn now to some problems for sophistication.


YOU JUST
Can't Lose
GOOD WAVES, GOOD STYLE, GOOD MUSIC
MADE BY
5¢
55 Stage & co. Ltd.
Indoors, Outdoors, all Around!

On scope

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- Response: None of these provide an argument for *radical* sophistication.

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- If we assume that all solutions differing merely by a κ-shift are empirically equivalent, then this κ-shift constitutes a symmetry transformation.
- As Dewar articulates, here sophistication proceeds by 'forgetting' the preferred origin of $\mathbb{R}$.

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- Cf. the renunciation of haecceities—primitive identities of spacetime points across possibilities—in the sophisticated substantivalism case.
- In both cases, the symmetry-related solutions are isomorphic—so we are deploying *traditional* sophistication.
- This provides no argument for (or clarification of) *radical* sophistication.

Example 2: Left and right hands

- Consider a 'theory' (in first-order logic) with two predicates, L and R, and obeying the two 'equations'

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- Dewar refers to an L/R-swap as a 'symmetry'—but not obvious that this is a symmetry in the relevant sense of empirical equivalence.
- Even restricting to the empirically equivalent L/R-swaps, sophistication in this case is a rejection of quiddities—it is, thus, a form of traditional—not radical—sophistication.

An empty realism?

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- There is a more general concern with the very idea of radical sophistication: To simply *insist* that all symmetry-related solutions be regarded as being isomorphic simply appears to be begging the interpretative question—of theft over honest toil.
- Dewar seems to think that one can be a realist (simpliciter) without having to make any commitments as to which parts of a theory one is realist *about*—that is, without having to commit to realism about anything specific. But is this realism worthy of the name?

Recourse to reduction

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- Dewar concedes that
  if we want to know the answers to specific questions about the nature of a theory's ontology and ideology, then [a reduced theory] is invaluable. (Dewar 2015, p. 326)
- But in that case, what work is radical sophistication doing towards explicating the ontology of symmetry-related solutions? And how does it sidestep the problem that a reduced theory (and interpretation thereof) need not necessarily exist?

It is puzzling how (radical) sophistication affords any insight into the ontology of symmetry-related solutions *at all*.

Today

1. **Definition of symmetries:** (J.R. & T.M-N., 2020b)
   - Symmetries should not be defined in epistemic terms—on pain of redundancy/lack of faithfulness to physics practice.
   - Those symmetries which are *discovered* to relate empirically equivalent solutions should be involved in symmetry-to-reality based reasoning (by Occam's razor).
2. **Interpretation/motivation:** (J.R. & T.M-N., 2020a)
   - Symmetry-related solutions should only be regarded as being physically equivalent when we have to hand a coherent explication of their common ontology.
3. **Reduction/sophistication:** (N.M. & J.R., 2020)
   - When symmetry-related solutions are isomorphic, we may appeal to (traditional) sophistication to explicate the common ontology of those solutions.
   - When symmetry-related solutions are not isomorphic, we must appeal to reduction (or internal sophistication) to explicate the common ontology of those solutions.
   - As a means of explicating the ontology of symmetry-related solutions, radical sophistication is uncompelling.

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