Introduction

What and Why of Physical Symmetries

Symmetries and Conserved Quantities

The Plan

I plan to explore the following questions: what explains symmetry principles in physics? And do symmetry principles explain conservation laws?

Explaining Dynamic Symmetries

What explains dynamic symmetries?
What does the symmetry to unreality inference tell us about the relationship between dynamic symmetries and spacetime structure?

Part 2: Do symmetry principles explain conservation laws? If so, how?:

- Explanation by constraint [Lan16]
- Grounding Explanation [Sch16], [Wil16].
Symmetries: What?

- A geometric symmetry transformation takes us from one shape to another which has the same geometric structure as the first.
- In general, symmetry transformations are transformations of a mathematical object which preserve its structure.

Symmetries, Explanation, and Grounding

Physical Symmetry

- Physical symmetries similarly preserve structure.
- Symmetries of physical laws are maps from solutions to solutions.

Symmetries: Galileo’s Ship

Physical symmetries are connected to observability.
- Galileo noticed that velocity boosts were unobservable.

Galileo noticed that velocity boosts were unobservable.
- If you were in the hold of a ship, no experiment you could do would determine whether the ship was moving.
- Velocity boosts are a symmetry of classical mechanics. What does this tell us?
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Lessons of the Ship

Physical symmetries are connected to observability and reality.

- **Symmetry to unobservability:** Measurements internal to a system cannot distinguish symmetry-related states.
- **Symmetry to unreality:** Quantities which vary between symmetry-related states (variant quantities) are not real.

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The Symmetry to Unreality Inference

- It's widely accepted that if a quantity varies between symmetry-related states, it is not real. [Das18], [Dew19]
- But what sort of inference is this?
- Plausibly, it is inference to the best explanation.
  - Two arguments support this view.

The Argument from Occamism

- The inference draws support from Occam’s razor: variant structure is surplus structure, and so believing in it violates Occamist principles.
- Occam’s razor is a constraint on inference to the best explanation.
- Conclusion: the inference from dynamic symmetries to spacetime structure is an inference to the best explanation.

The Argument from Alternatives

- The inference is not deductive.
- The inference is not inductive, or at least not enumerative induction.
- Conclusion: the inference from dynamic symmetries to spacetime structure is abductive: it is an inference to the best explanation.
What sort of explanation is this?

- If the symmetry-to-unreality inference is a case of inference to the best explanation, then the lack of spacetime structure must explain the dynamic symmetry.
- But what sort of explanation is this?
  - It’s not a causal explanation. So there are two prominent options:
  - It could be a case of explanation by constraint.
  - It could be a grounding explanation.

Constraint vs. Grounding

Case for grounding explanation:
- These transformations connect *intrinsically identical* states.
  - These quantities *constitute* the statespace and give it structure.
- Our dynamics is a function of intrinsic qualities. [Shung], [Edd14], [Fie80].
  - This is plausibly a *grounding principle* or *law of grounding* [Sch17], [Gla16], [Wil15]; on my view this should fall out of the metaphysics of laws.
- Unclear how spacetime structure could govern the dynamic laws, or which is more necessary.

A Puzzle About Negative Grounding

- What exactly grounds the dynamic symmetries?
  - Is it the presence of some spacetime structure, or
  - The lack of other spacetime structure (e.g. absolute velocities)?
- If the latter, how does the lack enter in the grounding relation? Similar issues to causation by omission are lurking...
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Symmetries and Conservation Laws

- The symmetries of classical mechanics in its Lagrangian formulation are those transformations which leave the Lagrangian unchanged (velocity boosts, spatial shifts, temporal shifts, and rotations).
- Noether's theorem shows that for any continuous variational symmetry of a Lagrangian, there is a conserved quantity.
- Worth noting: there is an inverse Noether's theorem, which shows that for every conserved quantity there is a variational symmetry.

Explanatory Options

Are the Noether theorems explanatory? Here, I consider three answers to this question:
- Yes: The symmetries explain conservation laws by governing or constraining them. The symmetries are metalaws.
- Yes: The symmetries explain conservation laws by grounding them.
- No: Both symmetries and conservation laws are grounded by the dynamics. The Lagrangian explains it all.

Symmetries and Conserved Quantities

Spatial Translation Symmetry \(\rightarrow\) Conservation of Momentum

Rotational Symmetry \(\rightarrow\) Conservation of Angular Momentum

Roadmap

- Introduction
- What and Why of Physical Symmetries
- Symmetries and Conserved Quantities

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**Constraint vs. Grounding**

### Constraint Explanation
- Explanans is *more necessary* than explanandum.
- Degree of necessity associated with counterfactual resilience [Lan09], [Lan16].
- *Governing* metaphor.

### Grounding Explanation
- Explanandum *asymmetrically depends* on explanans.
- Hyperintensional: explanandum and explanans may be have the same degree of necessity.
- *Building or constitution* metaphor

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**Case for Grounding: Hyperintensionality**

If symmetries explain conservation laws via Noether’s theorem, this explanation is hyperintensional:
- The converse Noether’s theorem shows that these are necessarily correlated.
- On the grounding picture, this is no problem: like Socrates and \{Socrates\}, there can be a dependence despite necessary equivalence.

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**Constitutionality**

- On my view, the symmetry principles are grounded in the world’s property structure.
  - Symmetry-related states are *intrinsically identical*.
- This fact—about the intrinsic identity of states—adds structure to the state space of our theory.
- The conserved quantities are functions on the state space.
- The symmetry principles provide structure to the state space which *constitute* the conserved quantities.

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**Constraint vs. Grounding**

### Constraint Explanation
- X Explanans is *more necessary* than explanandum.
- ?? Degree of necessity associated with counterfactual resilience [Lan09], [Lan16].
- X *Governing* metaphor.

### Grounding Explanation
- ?? Explanandum *asymmetrically depends* on explanans.
- ✓ Hyperintensional: explanandum and explanans may be necessarily connected.
- ✓ *Building or constitution* metaphor
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Iterated Explanation

An attractive picture:

Conservation laws

\[ \text{Noether theorems} \]

Symmetries of dynamic laws

\[ \text{Account of laws} \]

intrinsic vs. extrinsic property structure

Undermining Nonexplanatoriness

The argument that the Lagrangian explains it all is undermined:

- [BH04] argues that the symmetries and conservation laws are jointly explained by the Lagrangian dynamics: neither explains the other.
- (One of) Brown and Holland’s arguments is that the converse Noether theorems show that there is no asymmetrical explanation.
- But grounding explanation allows for asymmetric explanatory dependence even between necessarily correlated facts.
- This undercuts one of Brown and Holland’s arguments (but does not refute their position).

Conclusion

- I’ve argued that that symmetry principles are grounded in spacetime structure.
- I’ve argued that the explanation of conservation laws is best understood as a form of grounding explanation.

References I


References II


References III


References IV

Erica Shumener, *Humeans are out of this world*, Synthese (forthcoming).
