Symmetries, Explanation, and Grounding

Michael Townsen Hicks

University of Birmingham

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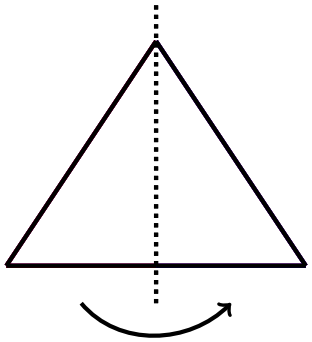
Roadmap

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].

Roadmap

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.

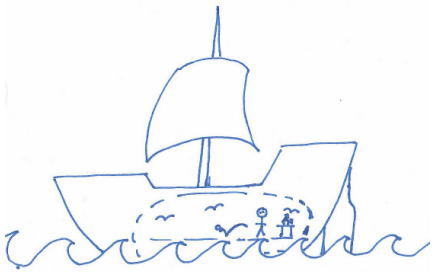
Physical Symmetry

- 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.

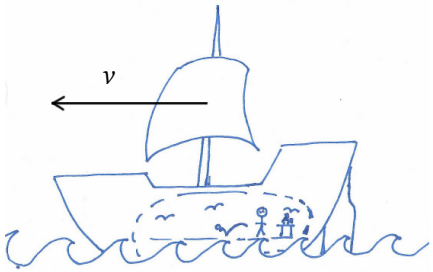
- Galileo noticed that velocity boosts were unobservable.



Symmetries: Galileo's Ship

Physical symmetries are connected to observability and reality.

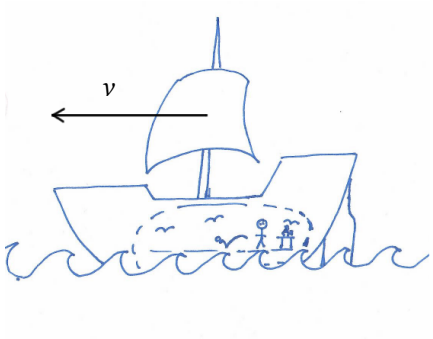
- Galileo noticed that velocity boosts were unobservable.
- If you were in the hold of a ship, no experiment you could do would determine whether the ship was moving.
- Velocity boosts are a symmetry of classical mechanics. What does this tell us?



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.



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

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 via *grounding principles*.
- hyperintensional: explanandum and explanans may be have the same degree of necessity.
- *Building* or *constitution* metaphor

Constraint vs. Grounding

Case for grounding explanation:

- These transformations connect *intrinsically identical states*.
  - These quantities *constitute* the statespace and give it structure.
- Our dymanics 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...

Roadmap

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 a inverse Noether's theorem, which shows that for every conserved quantity there is a variational symmetry.

Symmetries and Conserved Quantities

Spatial Translation Symmetry $\longleftrightarrow$ Conservation of Momentum

Rotational Symmetry $\longleftrightarrow$ Conservation of Angular Momentum

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.

Constraint vs. Grounding

Constraint Explanation

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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.

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.

Constraint vs. Grounding

Constraint Explanation

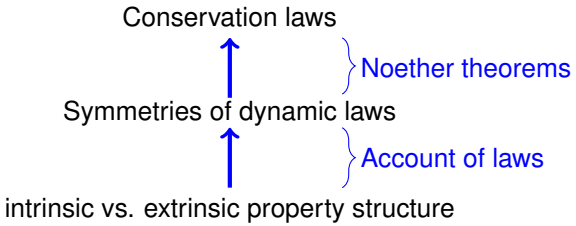
- X Explanans is *more necessary* than explanandum.
- ?? Degree of necessity associated with counterfactual resilience [Lan09], [Lan16].
- X *Governing* metaphor.

Grounding Explanation

- ?? Explanandum *asymmetrically depends* on explanans.
- ✓ hyperintensional: explanandum and explanans may be necessarily connected.
- ✓ *Building* or *constitution* metaphor

Iterated Explanation

An attractive picture:



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.

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