From Models to Reality: A Plea for Caution

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Main task of interest: Drawing metaphysical conclusions from physical models (i.e. a realist project)
Main claim: Care is needed!

- A trivial claim? Who would advise against caution?
- Underdetermination of metaphysics by theories
  - Poincaré (1902)
- Delicate middle way between conventionalism/instrumentalism and naive realism
  - Working posit realism? (Kitcher, 2001)
  - Motivational realism
1. Illustrating Naive & Motivational Realism

2. Elaborate Case Study: Absolute Mass in Newtonian Gravity
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Naive realism

- Seeming **consensus** in Phys and PhilPhys communities on
  - Symmetry-to-reality inferences
  - Duality-to-reality inferences

- **Typical claims**
  1. *Invariance Principle*: Only quantities invariant under the symmetries of our theory are real. *(Saunders, 2007; Baker, 2010; Dasgupta, 2015, 2016; Dewar, 2015; Dirac, 1930; Earman, 1989; Greaves and Wallace, 2014; Møller-Nielsen, 2017; North, 2009; Nozick, 2001; Weyl, 1952)*
  2. The equivalence class of dual/symmetry-related models is what is real *(Weyl, 1918a,b)*
  3. Dual/symmetry-related models represent the same physical state of affairs *(Rickles, 2016; de Haro, 2016, for unextendable theories only; see Read & Moller-Nielsen, ms, for an opposing view)*

- **Paradigmatic case**: Newton was at no point in time justified in believing in absolute velocities.
Some worries

- What is supposed to motivate the Invariance Principle?
- Undetectability? (Møller-Nielsen, 2017; Read & Møller-Nielsen, ms)
- Are we guaranteed that a reformulated theory that does map models to possible worlds in a one-to-one fashion could always be found? (Møller-Nielsen: No)
- Without such a reformulation, which picture of the world are we subscribing to exactly?
- Dualities: often clearly distinct physical states of affairs
Some more worries

- Is it always clear what the symmetries are?
- What about symmetries that are spontaneously broken? (Earman, 2004; Smeenk, 2006)
- Haecceitism, qualitativism & essentialism
- Many models are designed for a specific purpose (description, prediction, explanation) and specific domain of application only, involving strong idealizations. (Jacquart, 2016)
Interpretational vs motivational view [Symmetries]

**Interpretational View [Symmetries]**
Symmetries allow us to *interpret* theories as being committed solely to the existence of invariant quantities, even in the absence of a metaphysically perspicuous characterisation of the reality which is alleged to underlie symmetry-related models. (Møller-Nielsen, 2017, p.4)

**Motivational View [Symmetries]**
Symmetries only *motivate* us to find a metaphysically perspicuous characterisation of the reality which is alleged to underlie symmetry-related models, but they do not allow us to interpret that theory as being solely committed to the existence of invariant quantities in the absence of any such characterisation. (Møller-Nielsen, 2017, p.4)
Motivational view [Two Variants]

- Isomorphic models $\rightarrow$ no reformulation needed; only modest structuralism
- Non-isomorphic models $\rightarrow$ reformulation needed

(Moller-Nielsen, 2017)
Interpretational vs motivational view [Dualities]

(Read & Møller-Nielsen, manuscript)

**Interpretational View [Dualities]**

1. Interpret duality-related models as representing the same possible world; Then we may but don’t have to:
2. Identify those models and quotient them out of the space of dynamically possible models (DPM);
3. Find a metaphysically perspicuous characterisation of the reduced set of DPMs

**Motivational View [Dualities]**

Existence of dual models *motivates* finding a shared metaphysically perspicuous characterisation (3); only if that is found do we move on to interpret the models as representing the same possible worlds (1) and potentially identify them (2).
Naive vs Motivational Realism

**Naive realism**
Models that are empirically equivalent are invariably interpreted as representing the same possible world; they may be identified and quotiented out of the space of DPMs.

**Motivational or Sophisticated Realism**
The existence of empirically equivalent models only motivates us to find an underlying metaphysically and explanatorily perspicuous characterisation, but these models cannot be interpreted as representing the same possible world in the absence of any such characterisation.
The motivational view illustrated I

Absolute Position

- Static Leibniz Shift & Hole argument against manifold substantivalism
- Motivational view: models are isomorphic
  - → No reformulation needed
  - → A modest structuralism (sophisticated substantivalism) suffices to find a shared metaphysically perspicuous characterisation
  - → Symmetry-related models can then be identified
The motivational view illustrated II
Absolute velocity

- Kinematic Leibniz Shift
- Motivational view: models are non-isomorphic
  → We are motivated to find a shared metaphysically perspicuous characterisation: Neo-Newtonian Spacetime
  → In the absence of such, Newton was justified in believing in absolute velocity.
Electromagnetism: Leibniz Gauge Shift of vector potential

- Møller-Nielsen: models are not isomorphic → we are motivated to find a reformulation in terms of the Faraday tensor; once found the gauge shifted models can be interpreted as representing the same physical state of affairs.

- What about the Aharonov-Bohm Effect?
- Other theoretical virtues, such as providing a local explanation, are also relevant!

(Wu & Yang, 1975; Healey, 1997; Maudlin, 1998; Healey, 1999; Holland, 1993; Wallace, 2014)
Outline

1. Illustrating Naive & Motivational Realism

2. Elaborate Case Study: Absolute Mass in Newtonian Gravity
Absolutism vs Comparativism about Mass

**Absolutism**

Mass ratios are true in virtue of more fundamental determinate absolute masses.

**Comparativism**

The denial of absolutism.
Bad reasons for comparativism

- Numerical value used to represent absolute masses depends on conventional choice of unit
- A mass of ‘4kg’ does not represent anything intrinsically ‘4-ish’ about the object in the way that the number of corners of a square does.
- Determinable magnitudes of an object such as mass can only be expressed, non-dynamically, by comparing it to the magnitude of another object. (‘kinematic comparativism’)

(NM, 2017)
Some more bad reasons for comparativism

- Since absolute mass magnitudes are qualitatively indistinguishable, the mapping from mass magnitudes to the \([\text{quantity} \cdot \text{unit}]\) representing them is underdetermined.

- A passive mass scaling (i.e. change of units) does not change the physics, and is thus a symmetry.

- Even if an active mass scaling leads to observable differences, we could and should compensate for this by changing Newton’s constant accordingly. (Roberts, ms)
Response

- We don’t think a vector is not real because it’s coordinate description depends on a frame. (North, 2009) So why would we think absolute masses are not real just because the quantities used to represent them change when we change units?

- **Dynamic Comparativism:** Physical observables depend only on mass ratios, not on further absolute masses in virtue of which the mass ratios hold. (NM, 2017)
Comparativism’s bucket

\[ F_g = G \frac{mmM}{r^2} \]

\[ v_e = \sqrt{\frac{2GM}{r}} \]

(Baker, 2014; NM, 2017)
Motivation to find a new theory

- Active mass scaling is *not* a symmetry, but leads to detectable differences.

→ Absolute masses *explain* the different possible evolutions of the system!

- Nevertheless, absolute masses in some sense still undetectable: expressible (non-dynamically) only via comparisons

- Moreover, we only have empirical access to the mass times Newton Constant → wiggle room

→ Motivation to find a reformulated theory without absolute masses
Machian comparativism

\[ G = \frac{\gamma}{\sum_k m_k} \quad \rightarrow \quad F_{\text{grav}} = \gamma \frac{m_i m_j}{r^2 \sum_k m_k} \]

Despite being empirically equivalent to absolutist Newtonian Gravity, mass scaling is a symmetry and absolute masses are not required.
Conclusions

1. Drawing metaphysical conclusions from models of a theory is highly non-trivial, but possible.

2. When there is a symmetry, or a quantity that is in some sense undetectable, we are only motivated to find a reformulation of the theory (or a more metaphysically perspicuous characterisation of it) that does without that quantity. Until such is found we are justified in committing to that quantity.

3. Paradigmatic case: Newton was justified in believing in absolute velocities, until Neo-Newtonian spacetime was postulated.

4. Despite absolute masses being in some sense undetectable/unexpressible, comparativism only stands a fighting chance once Machian comparativism is put on the table.
A1. Virtual particles
A2. Naturalness
A3. LHC, dark matter & gravity

B1. Computer simulations
B2. Model building
B3. Novelty & Credibility

www.lhc-epistemologie.uni-wuppertal.de/


J. Read & T. Møller-Nielsen (manuscript), ‘Motivating Dualities’

D. Rickles (2016), ‘Dual Theories: ‘Same but Different’ or ’Different but Same’?’, forthcoming in *Studies in History and Philosophy of Modern Physics*.

J.T. Roberts (ms), ‘A case for comparativism about physical quantities’, academia.edu


