ON THE NOTION OF PRIMITIVE ONTOLOGY
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OUTLINE

- Methodology
- Primitive Ontology
- Local Beables $\approx$ Primitive Ontology
- The Role of Mathematics in Physical Explanations
- Primitive Ontology and Realism
**Methodology**

- How theory meets the world?
- A theory starts with a *Phenomenology*

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  The domain of physical facts that a theory should be able to explain;

  → several aspects are related: mathematics, physics and experience

  **Manifest/Scientific Image of the world**

  - Reality how we perceive it
  - World’s description given by a certain theory
**Methodology**

- **Physics**
  - Primitive Ontology – Physical laws

- **Mathematics**
  - Geometric/Algebraic Structures

- **Macroscopic Ontology**
  - Manifest Image of the world
  - Subjective Experiences

- **Experience**
Methodology

Einstein’s epistemological schema:

i. We have the $E$ (experience of the world – empirical data);

ii. $A$ are the axioms from which we draw conclusions;

iii. NB: there are no *logical relations of necessity* between $E$ and $A \rightarrow$ this connection can be modified in time;

iv. From $A$ we derive the $S$, particular statements with truth-value (T/F);

v. The $S$ are connected with the $E$ via experimental procedures;

vi. Question: how could we provide a sophisticated account for the $A$?
Methodology

- A physical theory could be:
  
  *Informationally completeness* → a description provided by a physical theory is informationally complete if every physical fact about a certain situation under observation is recovered by this description;

NB: a theory could be informationally complete even if does not provide a description of what is (supposed to be) physically real!

Physics can develop accurate and powerful models *without any ontological commitment* regarding the entities presented in the mathematical framework of the theory!
METHODOLOGY

- A mathematical representation of a certain theory could have different forms: e.g. Heisenberg Matrix Mechanics and Schrödinger Wave Mechanics;

- In Classical Electromagnetic Theory we can describe a certain physical situation in term of the field $\mathbf{E}$ and $\mathbf{H}$, but we could describe the same situation with the potential $\mathbf{A}$ and $\phi \rightarrow$ and with different potentials!

Keep the distinction between mathematical and physical entities as sharp as possible!
METHODODOLOGY

- A physical theory could be *ontologically* complete:

  Ontological completeness: a physical theory is ontologically complete if it provides an exact specification of the basic physical entities that are considered real in our world according to the theory.

- NB: informational vs. ontological completeness:
  - Ontological completeness $\rightarrow$ informational completeness

- It is not always valid:
  - Informational completeness $\rightarrow$ ontological completeness
**Primitive Ontology**

Primitive Ontology (PO): it is a *physical* assumption regarding the fundamental objects of the world: e.g. particles evolving in 3D space or in spacetime. Methodological role: PO coordinates the construction of a theory introducing certain features/constraints;

- *Primitive variables* $\rightarrow$ formal counterparts whose referents are real entities in the world (according to the theory);

- NB: these primitive variables are those from which our manifest image of the world is dependent on;
**Primitive Ontology**

Primitive Ontology (PO): it is a *physical* assumption regarding the fundamental objects of the world: e.g. particles evolving in 3D space or in spacetime. Methodological role: PO coordinates the construction of a theory introducing certain features/constraints;

- *Explanatory function* of the primitive variables: they are *primitive* because every physical object or phenomenon must be connected or explained in terms of PO;

- A physical theory with PO should explain a set of phenomena in terms of these P-Variables

- PO → Logical clarity of derivations of empirical predictions:
  
  \[ \mathcal{E}(\text{experiment}) \rightarrow Z(\text{outcome}), \text{ where } Z = \xi(PO), \]

- Z is a function of the PO!
**Primitive Ontology**

- Semantic account of Primitiveness:

- P-variables *can not be deduced* from other more fundamental notions

- Project of a *fundamental physical ontology*, or how the world should be *at the most fundamental level*;
**PRIMITIVE ONTOLOGY**

- Selection Rules: PO represents matter in spacetime → a particular PO can be combined with several dynamics, generating different theories ⇒ there is *no necessary rules/argument* to select a PO

- On this selection depends the plausibility of a physical description (subjective criterion?)

- PO → Epistemological Limitations:

  The theory decides what it is observable and what it is effectively knowable

- Example: GRWF - GRWm: times and spatial coordinates of the spontaneous collapses cannot be measured with arbitrary accuracy (the same is valid for particles’ positions in Bohmian Mechanics).
PRIMITIVE ONTOLOGY

- Primitive Ontology gives constraints in theory construction
- E.g. PO and Symmetries:
  - The solutions of dynamical equations yield the possible configurations (evolution) of the PO
  - Symmetries: the “possible histories” allowed dynamically are still possible solutions when transformed by a certain symmetry;
  - Example: P-variables: geometric entities in physical space
    - Spacetime symmetries apply to the PO, e.g. transforming trajectories: the new trajectories are still solutions of dynamical equations.
Local Beables

- John Stuart Bell (1976): *The Theory of Local Beables*

- *Be-ables vs Observ-ables* in the context of QM;
- Original idea: to describe clearly the *classical experimental devices* into the equations of QM → to make rigorous the formal apparatus of quantum theory

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Problems implicit here: vague definition of “observer”, fundamental role of measurements, arbitrary division between quantum and classical regime;
Local Beables

- If the exposition of experiments performed in the quantum context is made in classical terms, following Bohr, then the Bell’s point becomes clear;
- **Observable**: it is a (mathematically) well defined notion, *but physically?* ⇒ Which processes are observations?
- **Beable**: what the theory is about ⇒ *entities which are assigned to finite spatiotemporal regions* (Local);
- Local Beables: introduce a division between Physical and non-Physical entities;
- Bell’s example: in classical electromagnetism the fields $E$ and $H$ are real, physical entities, while the potential $A$ and $\phi$ are non-physical;

  Local Beables ⇒ Local Observables

  Local Observables \(\not\Rightarrow\) Local Beables
Local Beables

- Local Beables is a *physical* assumption referred to the basic physical entities in a theory: there is no obvious connection with a *fundamental ontology*; in these sense there is a difference between LB and PO

- Generally, LB is weaker than PO;

- LB and PO share the explicative role;

- PO in a broader sense could be used in the terms of LB
**Role of Mathematical Formalism**

- PO-LB approach (over-simplified): Dynamical Equations implement the primitive variables ⇒ explanations of physical phenomena or physical properties;

- Modal function: given the equations of motion, PO and initial conditions (trivially, in deterministic theories they have a special weight) are the *truth-makers* for the sentences of a given theory;

- E.g. BM is a deterministic theory of particles in motion with a well defined position at every given time $t$:

  \[ \downarrow \]

  given a certain initial configuration of particles and the equations of motion, *in every counterfactual situation we will end with the same final configuration*;

  Trivially, different configurations ⇒ different physical states;
ROLE OF MATHEMATICAL FORMALISM

Questions: what is the connection between mathematics and ontology? Could we infer the reality of mathematical objects from the role they play in physical explanations?

Indispensability Argument:

a) Mathematical objects play an indispensable role in our best scientific theories;
b) If an object play a fundamental role in a physical explanation, we have reasons to believe in its existence;
c) Thus, it is rational to believe in the existence of mathematical objects

Question: in which sense is mathematics indispensable?
ROLE OF MATHEMATICAL FORMALISM

- It seems that there is a \textit{logical gap} between indispensability and reality;
- Arbitrariness of mathematical apparatus (previous example: Heisenberg vs Schrödinger formulation of QM);
- \textit{Weak objection}: non causal power of mathematical entities: they cannot play a effective explanatory role since they are non causally active; \textit{Weakness}: \textit{what about non causal explanations}?
- Stronger Objection: Do mathematical entities play effectively an explanatory role or, are the physical entities represented by these object responsible for the explanations? \textit{Possible Reply}: this begs the question: we are asking if genuine mathematical explanations of physical phenomena are possible;
ROLE OF MATHEMATICAL FORMALISM

- Begging the Question? Even if we admit that genuine mathematical explanations of physical phenomena do exist, which *physical information* would we obtain from this sort of explanations?
- How does mathematics contribute in explanations?
- Answer: mathematics is fundamental in its inferential nature; where usually does math come in an explanation? At the level of physical laws: they are implemented in order to move something (in or approach the PO-LB) to have in principle an optimal description of physical phenomena;
- Mathematics is an indispensable tool!
ROLE OF MATHEMATICAL FORMALISM

- Physics works through Mathematics: a theory contains several mathematical objects

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- Question: which mathematical object has a physical meaning?

Argument: if in a physical theory there is an equation for the evolution of a certain mathematical object, then one is rationally justified to have an ontological commitment to this object; in other words, one is justify to consider this object as representing a physical entity.

- This argument is not always valid; e.g. realism about the wave function: $\psi$ could be considered a fundamental physical object but in this case the analysis benefits/costs brings us to claim a set of auxiliary assumptions difficult to sustain;
ROLE OF MATHEMATICAL FORMALISM

- Analogy: Math and Computer Programming
  - Suppose that a theory is an algorithm with which we describe reality;

- Then there are several ways to produce an “output” (solutions of dynamical equations) ⇒ using different mathematical strategies;

- But first we have to select the variables which will be implemented ⇒ PO-LB!

- E.g.: two physical theories are physically equivalent iff they give the same histories for the PO, and PO is what remains invariant under physical equivalence;
PRIMITIVE ONTOLOGY AND REALISM

- The Primitivist approach entails an ontological commitment to the fundamental entities of a theory ⇒ they are considered as *real*;
- However, in virtue of its plausibility and simplicity in physical explanations even an empiricist/instrumentalist could prefer a theory with a clear ontology (avoiding the ontological commitment);
- Another reason is important here:

  Practical/computation advantages (see X. Oriols Applied Bohmian Mechanics, examples from nanotechnology to quantum chemistry).
REFERENCES

- Slide 3 is a simplification of “Cos’è la Filosofia della Fisica”, N. Zanghì’s lecture available on his personal webpage [http://www.ge.infn.it/~zanghi/filo/fdf2012.html](http://www.ge.infn.it/~zanghi/filo/fdf2012.html)