On the notion of primitive Ontology

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Outline

- Methodology
- Primitive Ontology
- Local Beables ≈ 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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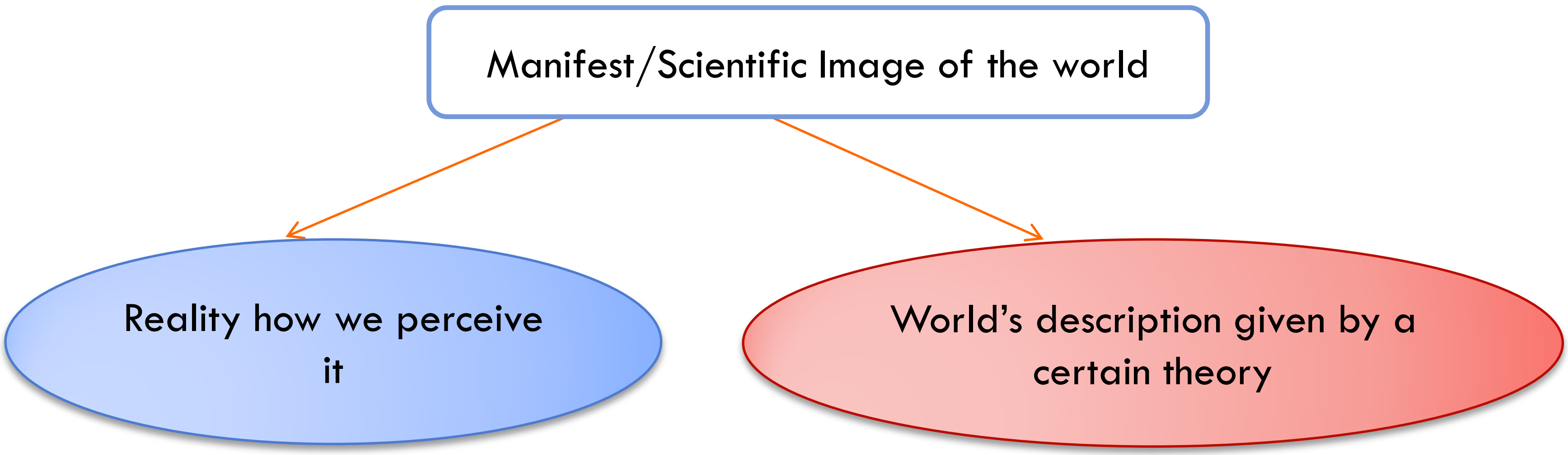
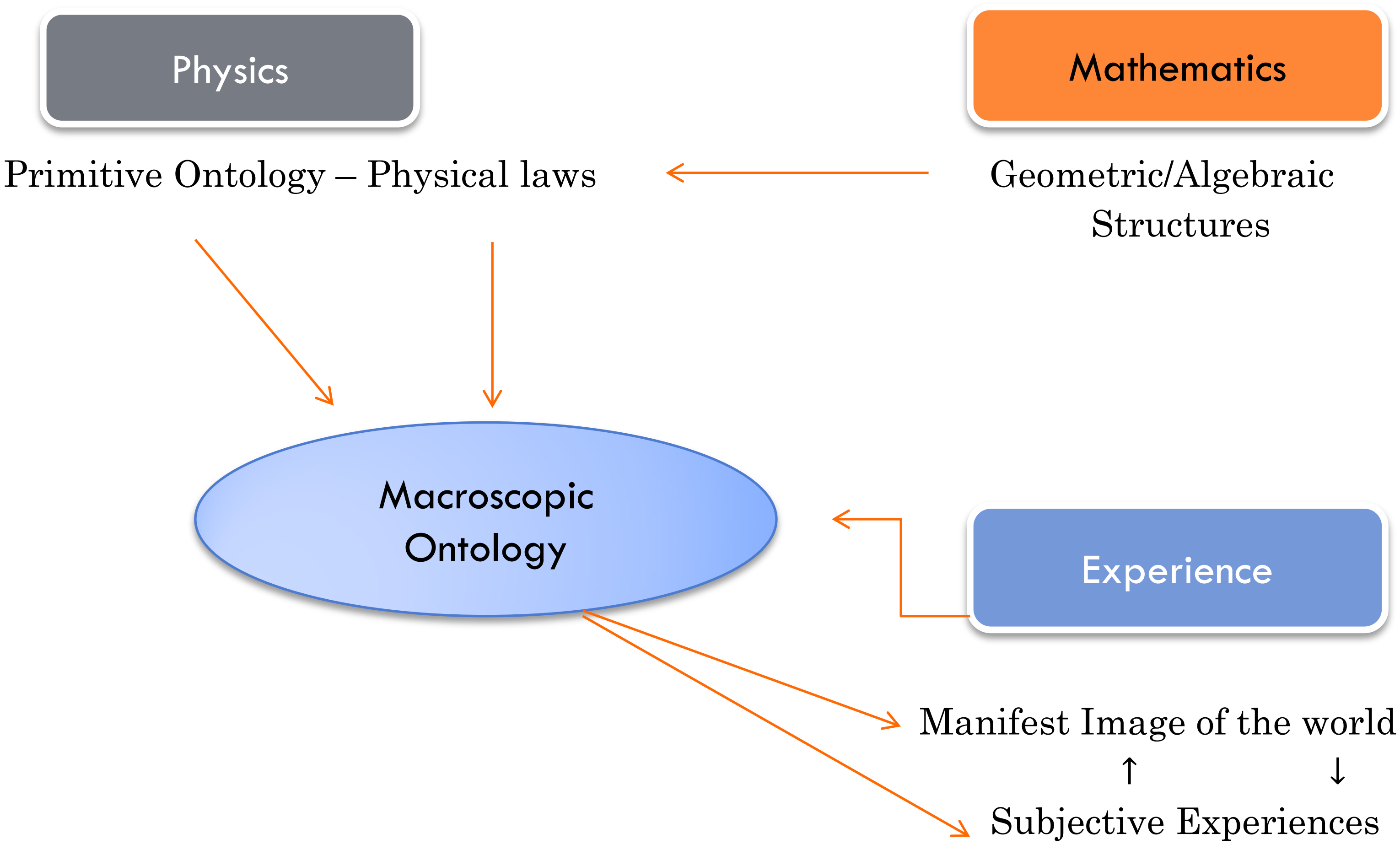
The domain of physical facts that a theory should be able to explain;

→ several aspects are related: mathematics, physics and experience



METHODOLOGY



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* → 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 **E** and **H**, but we could describe the same situation with the potential **A** and ϕ → and *with different potentials!*

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

METHODOLOGY

- 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 → informational completeness

- it is not always valid:

Informational completeness → 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* → formal counterparts whose referents are real entities in the world (according to the theory);

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- 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;

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- 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:

$$\mathcal{E}(experiment) \rightarrow Z(outcome), \text{where } Z = \xi(PO),$$

- Z is a function of the PO!

Primitive Ontology

- Semantic account of Primitiveness:

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

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- 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

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- E.g. PO and Symmetries:
- The solutions of dynamical equations yield the possible configurations (evolution) of the PO

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- Symmetries: the "possible histories" allowed dynamically are still possible solutions when transformed by a certain symmetry;
- Example: P-variables : geometric entities in physical space

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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*

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- *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 ϕ are non-physical;

Local Beables ⇒ Local Observables

Local Observables ⇏ 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

PO in a broader sense could be used in the terms of LB

- LB and PO share the explicative role;
- Generally, LB is weaker than PO;

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-maker*s 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 *logical gap* between indispensability and reality;
- Arbitrariness of mathematical apparatus (previous example: Heisenberg vs Schrödinger formulation of QM);
- *Weak objection*: non causal power of mathematical entities: they cannot play a effective explanatory role since they are non causally active; *Weakness: 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? *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: ψ 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 way 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:

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

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