

**STRUCTURAL REALISM  
AS A METHODOLOGICAL  
PROGRAM TO INVESTIGATE  
THE ONTOLOGY OF  
BOHMIAN MECHANICS**

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# STRUCTURAL REALISM

**Main claim:**

- **Centrality/Fundamentality of structure**

It aims to address the following issues:

- **Change of science**
- **Problem of underdetermination**
- **Interpretation of elements of physical theories**
- **Interpretation of physical theories → how to account for emergent reality & how to differentiate mathematical artifact from representational content.**

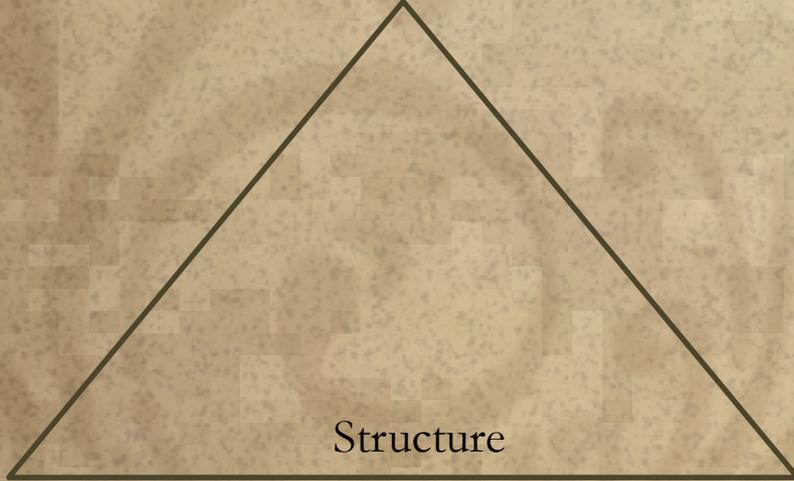
# HIERARCHY

According to structural realism:

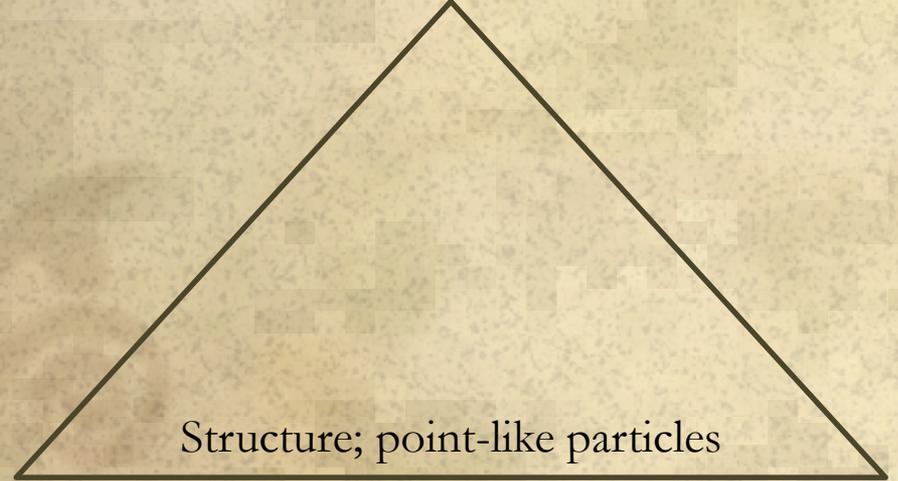
**“The existing entities described by a scientific theory are organized into a hierarchy, in which ‘structure’ occupies the most fundamental position.” (Roberts 2011, p. 49)**

# HIERARCHY

Structure; objects;  
properties



Structure; objects;  
properties



# ONTIC STRUCTURAL REALISM

## RECONSTRUCTION

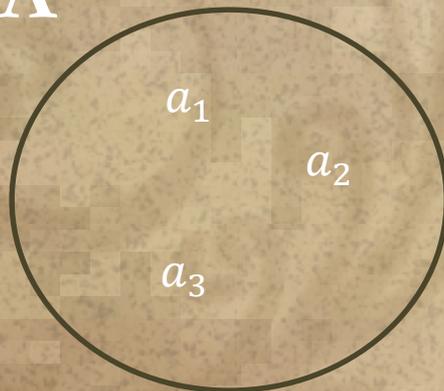
“Such views are defensible only if they are materially adequate, only if they can ‘reconstruct’ the world of common sense (...). There is room for disagreement over what exactly “reconstruction” amounts to, but at a minimum: when a metaphysical theory reconstructs ordinary sentences  $\varphi_1 \dots$  as replacement sentences  $\psi_1 \dots$ , ordinary (...) evidence must not refute the view that, strictly speaking, it is  $\psi_1 \dots$  rather than  $\varphi_1 \dots$  that are true. The metaphysician needs reconstruction in order to face the tribunal of experience.” (Sider 2008, p. 129).

# SAVING THE APPEARANCES

(Sider 2008)

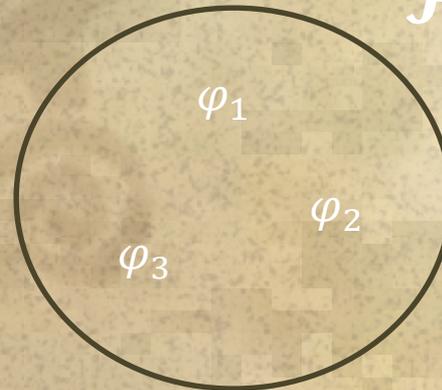
$$G_{\mathfrak{F}}(\varphi) = a$$

A



set A of possible descriptions of the world stated in the language of ordinary experience

$\mathcal{F}_{\mathfrak{F}}$



set  $\mathcal{F}_{\mathfrak{F}}$  of fundamental possibilities for the world;  $\varphi \in \mathcal{F}_{\mathfrak{F}}$  specifies a way the world might be, in terms that T takes to be fundamental.

# ONTIC STRUCTURAL REALISM

- **RECONSTRUCTION** means being able to spell out physical reality in fundamental terms;
- **But Structural Realism may agree with Melia Joseph (1995) - the best theory may not be the best theory *for us*:** “However, the above example shows that we can know there is a better theory whose ontological commitments are different from those of our best theory. In this situation, even a Quinian can see that **we should believe only in the entities which the better theory says exists** - even if, through uneliminable ignorance, this theory will never be our best theory.” (J. Melia 1995, p. 227)
- **Problem: According to OSR, Physics should inform metaphysics. Does it not rely on the link ‘best-theory-true ontology?’**

# Interpretation of physical theory

## Difference between realist and structural realist

“In our opinion, the really important difference between the two positions concerns how much of the mathematical formalism is rejected as “mere artefact” and how much is retained as representational. We think that the structural realist has a clear methodological proposal for making this distinction which differs significantly from that of the substantialist. The difference in ontological commitments is indicative of a difference in method for distinguishing which aspects of the formal presentation of a theory are candidates for representation, and which are surplus formal devices needed for the presentation of the theory but not part of the representational content. Realists say: look at what we need in order to write down a model, mathematically, and take a philosophically literal approach to physically interpreting the mathematical formalism” (Brading & Skiles 2012, preprint)

**A dialogue between a Realist and  
a Structural Realist**

R: We are realist of what our best physical theory tells us about the world. Therefore, we take the laws of physics, as formulated in that theory, to be the guide for the ontology. Its dynamical laws are about what is fundamental. We ask: what are the mathematical objects we need to write down our best theory? Those mathematical objects are fundamental pieces of our ontology.

SR: But here you are confusing the mathematical domain with the physical domain. You should keep the two separate.

R: Okay, the mathematical objects that are fundamental represent physical entities of our world (with a one-to-one correspondence).

SR: But there are many formulations of the same physical theory. How are you going to choose between many formulations?

R: Our laws are part of the best possible system of laws, hence we should take those laws to be informative about the ontology of the world.

SR: But the best theory for us may not be the best theory. There can be always better theories than our best theory.

R: But then how can you say whether a theory is good or bad without criteria like informativeness and simplicity?

SR: It doesn't matter whether there are different formulations of the same theory. We might agree with the claim that the dynamical laws are about what is fundamental and still acknowledge that the dynamical laws make use of a structure which may or may not be found in the physical world.

R: But how can you recognize whether a mathematical structure is also found in the ontology?

# Structural realism becomes a Methodological program

That Physics should inform  
Metaphysics is not enough...

# We need to establish criteria.

Dasgupta (2014, 2017), Esfeld et al. (2014, 2017)

- Unobservability (Undetectability);
  - problem: risk to fall in phenomenalism/berkelian view.

“JT: “If so, then you end up with a view where everything is grounded in phenomenal properties, bringing us dangerously close to phenomenalism or neo-Berkelean idealism. I thought the argument against individuals was supposed to stem from principles fairly uncontroversial to scientific realists; if the principles get us phenomenalism, they seem pretty controversial after all. I’m inclined to reject the argument before I let it push me to phenomenalism”

DS: “Well it’s not clear that that’s the right description of the resulting view! But even if it is, the principle only tells us to dispense with idlers when all else is equal. So if at some point along the road the resulting view violates some other principle you hold dear—epistemic conservatism, or some principle that leads to realism—then stop.” (Dasgupta & Turner 2017, p. 40)

- Physical redundancy.

**If we adopt those criteria:  
Generalism + No properties**

# Generalism

## (Rejection of Individuality)

“Starting with the charge of undetectability, the idea is that a primitive individual is “hidden” behind its qualities. We can detect those qualities and come to know that *something or other* has them, but according to individualism there is a *further fact of the matter* as to which individual it is, and I claim that this further fact is epistemically inaccessible. [...]

What about the charge of physical redundancy? Well, imagine a closed physical system composed of primitive individuals propertied and related in various ways. How it behaves over time depends *only* on qualitative facts about it, not on those further facts about which primitive individuals lie behind those properties and relations. So the particular primitive individuals that populate the system make no difference to how it evolves. As it might be put, the physics is “blind” to the primitive individuals themselves and “cares” only about the qualitative facts about the system.” (Dasgupta 2017, p. 12)

“If individualism were true then the individualistic facts of our world would lie beyond our epistemic ken.” (Dasgupta 2014, p. 6.)

# Generalism

## Dsgupta's confusion on individuals

“I argue against the view that the fundamental furniture of the material world includes of individuals, a view I call individualism. On this view the most basic, irreducible facts about our world include facts about what individuals are and how they are propertied and related to one another.” (Dasgupta 2009, p. 35)

**“As I said, we should reject primitive individuals (...) because they are physically redundant and undetectable.”** (Dasgupta 2009, p. 37 )

**“Yet, experience presents us with a world full of individuals.** If a theory that dispenses with primitive individuals cannot account for how the world appears then all else would be not be equal. At best, this objection points out that there is an onus on me to show that the alternative metaphysics I propose can account for how the world appears.” (Dasgupta 2014, p. 10.)

# Generalism

## GROUNDING

Individual facts (emergent) grounded in general facts (fundamental)

Suppose that the world consists of only three individual facts:

1. Nick is kind
2. Jane is generous
3. Nick is Jane's father

Which we can spell out as:

a is F

b is G

a bears R to b

These three individual facts are grounded in one general, holistic fact:

$$(\exists x)(\exists y)(Fx \& Gy \& Rxy \& x \neq y)$$

# Structural realism as plural grounding

«Is structuralism what ‘ontic structural realists’ like Ladyman and Ross have in mind when they talk of individuals ‘whose identity and individuality are secondary to the relational structure in which they are embedded’?

It is hard to say, in part because this talk of individuality is obscure in the extreme.

But suppose they had in mind the idea that each individualistic fact is grounded in facts about relational, qualitative structure.

Then, their view is that there is some qualitative body of fact responsible for each individualistic fact.»

(Dasgupta 2014, p. 14)

# PROPERTIES

- ❖ Suppose a property plays its causal role only contingently; its essence is a pure quality (quiddity)

But we cannot have access to this qualitative nature.

A difference in quiddity is not detectable (Undetectability).

- ❖ Suppose that categorical properties is tied together with the causal ones. Then it would be redundant.

## ➤ CAUSAL STRUCTURALISM ABOUT PROPERTIES:

In all possible worlds,  $x$  and  $y$  are instantiations of the same property iff they realize the same causal role.

(For each fundamental property, a causal profile constitutes the individual essence of a property. That is, the profile is both necessary and sufficient for each property.)

.....or ?

Allori:

## NO THEORETICAL PROPERTIES

“Both inertial and

gravitational mass are introduced through their dynamical role, namely as dynamical **parameters** that couple the motions of the particles to one another,

in short, mass tells us something about how

the particles move. Hence, the role of mass is the one of a parameter that expresses a dynamical relation among the atoms. [...]

If mass and charge, as well as the quantum state, express in fact **dynamical relations** among the particles that tell us something about their motion, then what remains as basic characteristic of the atoms is their position in space, given that motion is change in the spatial arrangement of the particles.” (Esfeld forthcoming, p. 6)

**How to interpret this claim? Bare particulars?**

# Example: Bohmian Mechanics

$$i\hbar \frac{\partial \Psi}{\partial t} = \left( -\frac{\hbar^2}{2m} \nabla^2 + V \right) \Psi$$

$$v_k^\psi = \frac{dQ_k}{dt} = \left( \frac{\hbar}{m_k} \right) \text{Im} \left[ \frac{\nabla_k \Psi}{\Psi} (Q_1 \dots Q_n) \right]$$

Two options of ramsification  
in Bohmian Mechanics:

$$\exists c_1 \exists c_2 ((D_1(c_1) \wedge D_2(c_2)) \dots$$

This is weak

$$D_1(\textit{Joe}) \wedge D_2(\textit{Sally}) \dots$$

This is complicate and long

## First puzzle:

Are we ramsifying too much?

What's the limit?

Remember the principle:  
ramsification should never force us  
to give up fundamental principles

## Second puzzle:

If we rule out properties, we have primitive individuality!

$$Q := (Q_1, Q_2 \dots Q_n)$$

$$Q' := (Q_2, Q_1 \dots Q_n)$$

**BUT THIS IS ABSURD!**

# Identity based Bohmian mechanics

We need set not  
tuples.

It does not matter  
which particle has  
which position.

$$Q = \{q_1, q_2, q_3 \dots q_N\}$$

$${}^3R^N$$

But then can we reformulate the laws?

## The Identity-based Bohmian Mechanics

$$\frac{dQ_1}{dt} = \frac{\frac{\hbar}{m_e} |\chi(Q_2)|^2 \text{Im}[\varphi(Q_1)^* (\nabla\varphi)(Q_1)] + \frac{\hbar}{m_\mu} |\varphi(Q_2)|^2 \text{Im}[\chi(Q_1)^* (\nabla\chi)(Q_1)]}{|\varphi(Q_1)|^2 |\chi(Q_2)|^2 + |\varphi(Q_2)|^2 |\chi(Q_1)|^2}$$

$$\frac{dQ_2}{dt} = \frac{\frac{\hbar}{m_\mu} |\varphi(Q_1)|^2 \text{Im}[\chi(Q_2)^* (\nabla\chi)(Q_2)] + \frac{\hbar}{m_e} |\chi(Q_1)|^2 \text{Im}[\varphi(Q_2)^* (\nabla\varphi)(Q_2)]}{|\varphi(Q_1)|^2 |\chi(Q_2)|^2 + |\varphi(Q_2)|^2 |\chi(Q_1)|^2}$$

# But the problem is reconstruction

The difference in the laws leads to different trajectories!

We are in front of two different theories.

We cannot recover

facts with primitive individuality.

Spelling out BM in terms of general facts  
leads to another theory.

This shows Dasgupta's confusion:

we cannot recover primitive individuality  
(not only by definition but also by facts)!

**We just deny completely the existence of  
Primitive Individuality  
Only derivative individuality exists**

# PARTICLES' DERIVATIVE INDIVIDUALITY

1. It is always the case that a particle has a definite location (position) in space-time.
2. For any instant of time, and for any two particles  $x$  and  $y$ , if  $x$  has position  $p_1$  and  $y$  has position  $p_2$ , and  $p_1 \neq p_2$ , then  $x \neq y$ :

$$\forall x, \forall y(((p_1x \& p_2y) \& (p_1 \neq p_2)) \rightarrow (x \neq y))$$

3.
  - 3a. For any instant of time, and for any two particles  $x$  and  $y$ , if at the same instant of time  $t_1$   $x$  is at  $p_1$  and  $y$  is at  $p_2$  and  $p_1 = p_2$ , then  $x = y$ :

$$\forall x, \forall y(((p_1x \& p_2y) \& (p_1 = p_2)) \rightarrow (x = y))$$

- 3b. For any instant of time, and for any two particles  $x$  and  $y$  having position  $p_1$  and  $p_2$  respectively, if the two particles are distinct, then their positions must also be distinct:

$$\forall x, \forall y((p_1x \& p_2y) \& (x \neq y) \rightarrow (p_1 \neq p_2))$$

Mistakes about Bohmian particles: can they cross?

# REPLIES FROM THE LITERATURE:

- **‘Nomological’ impenetrability (French & Rickles 2003):**  
“Since these equations are first-order, the trajectories of two particles which are non-coincident to begin with will never coincide. In effect the impenetrability of the particles built into the guidance” (French & Rickles 2003, p. 224)
- **Metaphysical Impenetrability (Esfeld et al. forthcoming) :** particles are impenetrable, they never cross, they bounce off each other.
- **Penetrability: (Brown 1996) :** particles can cross but then once they cross, they never separate again.  
**Penetrability: (Goldstein 2005), (Chen forthcoming):** particles’ trajectories can cross and have two distinct trajectories later on.

**No spatio-temporal individuality.**

**It seems that...**

- **EITHER WE READMIT INTRINSIC PROPERTIES**
- **OR WE ADOPT A DERIVATIVE RELATIONAL INDIVIDUALITY**

**$D_1(\textit{Joe}) \wedge D_2(\textit{Sally})$**

$D_1, D_2 \dots$  provide the conditions for particles' individuality  
But  $D_1, D_2$  take into consideration all the other particles'  
positions, which means that the kind of individuality is  
relational (or structural).

*Thank you!*

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