

# Structuralism, Laws, and Properties

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# The project of this paper

- **Proposal of a view which is a friendly criticism of Eliminativist Ontic Structural Realism (EOSR)**
- **Friendly:** Same core motivations
  - Defeat the pessimistic meta induction (PMI)
  - underdetermination and entanglement
  - parsimony/simplicity
- **Criticism:** Less objections
  - More successful in defeating the PMI
  - intelligible
  - not (too) revisionary
  - No conflation of mathematical and physical structure
- **The view:** There are **'thin' objects** without any other property but their spatial location, governed by **laws**

# Scientific realism and PMI

- Scientific Realism
- Objection: The Pessimistic Meta-Induction (PMI)
- Replies:
  - **Selective realism**: be realist about selected portions of the theory (the ones preserved in theory change)
    - **Eliminativist Ontic Structural Realism (EOSR)**:
      - There are no objects (individuals), only relations (structure)

# Motivations for Ontic Structuralism

- **Scientific Realism:**
  - We are justified in believing that our most successful scientific theories are (approximately) true
- Motivation: **No-Miracle** Argument:
  - It would be a miracle if theory were not true
- Objection: **The Pessimistic Meta-Induction (PMI)** Argument:
  - In the past, (what we now know are) false theories were successful

# Motivations for Ontic Structuralism

- Replies to the PMI:
  - **Selective realism**: be realist about selected portions of the theory (the ones preserved in theory change)
  - among which:
    - **Structural realism**: ‘structure’ is preserved, so be realist about ‘structure’
      - Epistemic Structuralism: no justification to claim we can know more than structure
      - Ontic Structuralism: there is nothing other than structure
        - **Eliminativist Ontic Structural Realism (EOSR)**:
          - There are no objects (individuals), only relations (structure)

# Motivations for Eliminativist Structuralism

- Arguments **for** EOSR:
  - 1- Underdetermination argument from quantum statistics
    - Two distinct metaphysical packages (Objects-as-non-individuals and objects-as-individuals) are **compatible with** data
  - 2- Argument from entanglement
    - Entangled states are best understood as **relata** of an entanglement structure
  - 3- Ockham's razor
    - (structure) > (objects + structure)

# Motivations for Eliminativist Structuralism

- Arguments for EOSR:
  - 1- Underdetermination argument:
    - Quantum statistics:
    - Two distinct metaphysical packages (Objects-as-non-individuals and objects-as-individuals) are **compatible with** data:
      - What is the case is underdetermined by the data,
      - Therefore (parsimony):
        - we should **retract** any metaphysical commitment that there are objects as individuals

# Motivations for Eliminativist Structuralism

- Arguments for EOSR:
  - 2- Argument from entanglement:
    - Entangled states are characterized by a **common wave function**, not determined by the states of the components (which possess no state at all)
    - Therefore, (assuming the wave function describes properties) we **cannot associate any property** to the individual states
    - Entangled states are best understood as **relata** of an entanglement structure
      - ex: singlet state
      - Composite system has spin 0; individual systems have no definite spin
        - They stand in the relation: “has spin opposite to”

# Motivations for Eliminativist Structuralism

- Arguments for EOSR:
  - 3- Ockham's razor:
    - Why postulate objects if one does not need to?
      - (structure) > (objects + structure)
    - This is connected with French's view on **properties and laws** (laws are primary, properties emerge from symmetries)
    - against
      - Humeans: Laws supervene on entities and their properties
      - Dispositionalists: Properties have active potencies, laws emerge
      - French's view:

# Criticisms of Eliminativist Structuralism

- Arguments **against** EOSR:
  - 1- The view is unintelligible (Chakravartty 2003)
    - Relations cannot exist without relata
  - 2- The view is too revisionary (Esfeld 2014)
    - A 'moderate' ontic structuralism in which there are 'thin' objects is enough
  - 3- The view collapses the distinction between mathematical and physical structure (van Fraassen 2006)
    - If only the structural aspects of the mathematical formalism are relevant to ontology, there is nothing to distinguish mathematical and physical structure

# Criticisms of Eliminativist Structuralism

- Arguments against EOSR:
  - 1- The view is unintelligible (Chakravartty 2003):
    - Relations cannot exist without relata
    - Possible response (French and Krause, 2006):
      - we do not require relations to be without relata, we just require relata **not to be individuals**
        - Quantum 'objects' can be understood with **non-classical logic**
      - A problem with such response:
        - **Undermines the simplicity** motivation

# Criticisms of Eliminativist Structuralism

- Arguments against EOSR:
  - 2- The view is too revisionary:
    - A 'moderate' ontic structuralism in which there are 'thin' objects is enough (Esfeld 2004)
    - The **burden of proof** is on the eliminativist, to motivate their view
      - Difficult balance between **simplicity** and **explanatory power**

# Criticisms of Eliminativist Structuralism

- Arguments against EOSR:
  - 3- The view collapses the distinction between mathematical and physical structure (van Fraassen 2006):
    - If only the structural aspects of the mathematical formalism are relevant to ontology, there is nothing to distinguish mathematical and physical structure
  - 4-The relationship between structure and laws is insufficiently spelled out

# Criticisms of Eliminativist Structuralism

- Arguments against EOSR:
  - 5- The view cannot really defeat the PMI:
    - (Chakravartty 2007): loss of mathematical structure in theory change
    - In particular, in the classical-to-quantum transition (Allori ms):
      - If the **wave-function** is part of the structure, since the wave-function has **no classical analog**, then there is radical discontinuity and structure is not preserved

# Criticisms of Eliminativist Structuralism

- Arguments against the **motivations** for EOSR:
  - 6- **Against underdetermination:**
    - A-(Saunders 2006): quantum objects are **weakly** discernible
    - B- underdetermination **can be broken** with ‘super-empirical’ virtues without ceasing to be a ‘good empiricist’
      - See later the view I defend!

# Quantum Ontology as Primitive Ontology

- EOSR: an interpretative framework of the quantum formalism
- Many find the quantum formalism **unsatisfactory**:
  - the measurement problem
- **Realist ‘interpretations’** of quantum formalism:
  - Bohmian and Everettian mechanics, GRW theory,...
- Controversy: the wave function plays a crucial role in all these theories, but **what *is* the wave function?**
  - **Wave function realism** (Albert 1996): the wave function represents matter
  - **Primitivism** (Allori, Goldstein, Tumulka, Zanghi 2008): the wave function is a nomological entity, matter is ‘made of’ 3-d entities (the primitive ontology, PO, of the theory)

# Quantum Ontology as Primitive Ontology

- PO: specifies **the nature** of the fundamental **material entities** (in 3-d space)
- The PO is **postulated** (rather than inferred from the formalism):
  - It provides the **simplest, most unifying** explanation of the phenomena
- **How matter behaves** is determined by the **law of temporal evolution of the PO**:
  - The ‘nomological’ variables (in quantum theories, the **wave function**)

# Quantum Ontology as Primitive Ontology

- PO: specifies **the nature** of the fundamental **material entities**
  - **Particles** – mathematically represented by points in 3-d space  
 $x$
  - **Fields** – mathematically represented by functions of 3-d points  
 $f(x)$
  - **Strings** – mathematically represented by 2-d objects in 3-d space  
 $(x,l)$
  - **Events (flashes)** – mathematically represented by points in 4-d space-time  
 $(x,t)$

# Quantum Ontology as Primitive Ontology

- How matter behaves is determined by the law of temporal evolution of the PO:
  - The variables in the laws are the ‘nomological’ variables
  - In quantum theories, the wave function is of this kind
    - It never represents matter, it determines how matter moves

# Quantum Ontology as Primitive Ontology

- **Macroscopic objects** are **composed** of the microscopic fundamental entities described by the **PO**
- **Properties** of macroscopic objects: **Bottom-up**
  - **Reductionist and compositional** approaches (as in classical mechanics)
- The PO is **postulated** (rather than inferred from the formalism):
  - It is the one which provides the **simplest, most unifying** explanation of the phenomena

# No Fundamental Properties

- The PO specifies the nature of the fundamental entities:
  - As such, the **only property** that one needs to specify to set the PO is **the one that determines its nature**
  - Ex: particles: they **only need their position** to be specified
    - They are (fundamentally) **points** in 3-d, without any other property
    - What distinguishes one particle from another is their location in space
    - There is **just ONE KIND** of particle → “all particles are identical” (Goldstein et al 2005)

## • ‘Thin’ objects!

- The **observed behavior** that suggests there are different kinds of particles is accounted for by the **laws of nature**

# No Fundamental Properties

- The **four** ingredients of the **'traditional' view**:
  - Space-time; fundamental things; fundamental properties; laws
    - **One law, many fundamental properties**:
      - We need fundamental properties to account for the observed different behavior of a proton and an electron (say)
- The **three** ingredients of **my view**:
  - Space-time; fundamental things; laws
    - **One kind of thing, 'many laws'!**
      - Matter *seems* to behave differently because there are many ways the same kind of law can be implemented (**effective laws**)

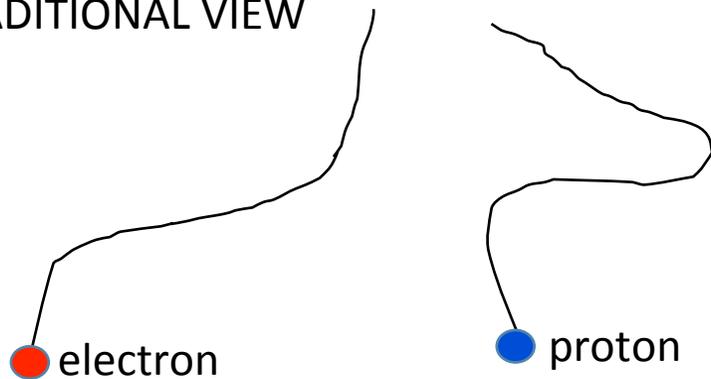
# Laws

- Ex:  $F = Gm_1m_2/r_{12}^2$
- In the traditional account, laws contain:
  - **Constants** (e.g. G): **fixed** and immutable → part of the definition of the law
  - **Parameters** (e.g.  $m_1, m_2$ ): **change** depending what the law is acting on → part of what defines matter, not of the laws
    - Body 1 and body 2 behave differently in the same circumstances even if they are acted upon by the same gravitational law because their masses are different
- In my view:  $F = H/r_{12}^2$ ,  $H = Gm_1m_2$  → laws **only** contain ‘**constants**’
  - ‘**Parameters**’ are part of the **law** too, they do not define matter
  - The law can be implemented in different ways:
    - There are many ‘**effective**’ laws, each for every kind of what in the traditional view is called fundamental entity
    - Body 1 and body 2 behave differently in the same circumstances because they are acted upon by a different effective law

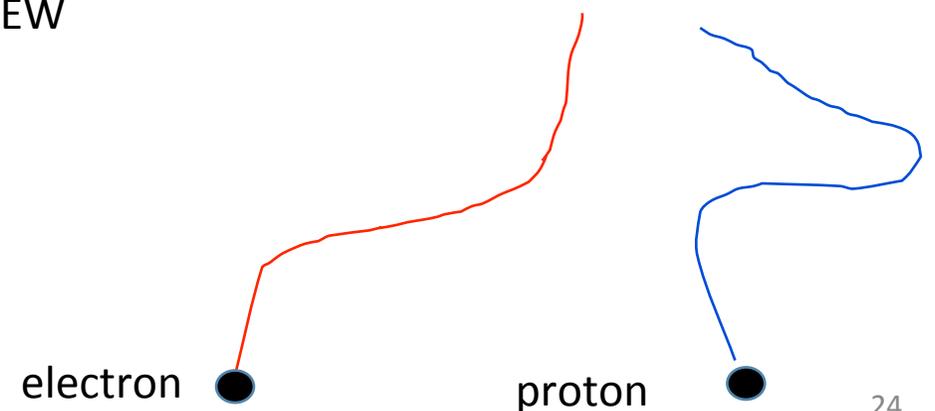
# Laws

- In my view:
  - A 'proton' is accelerated faster than an 'electron' in a gravitational field not because the 'proton' has a bigger mass than the 'electron'
  - Rather, because they are governed by **different effective laws**:
    - Proton:  $E_{law1} = H_1 / r^2$ , where  $H_1 = m_{proton} G m$
    - Electron:  $E_{law2} = H_2 / r^2$ , where  $H_2 = m_{electron} G m$

TRADITIONAL VIEW



MY VIEW



# Laws

- In the **quantum domain**:

- Ex: In Bohmian mechanics the law is:

- The k-th particle would evolve with a velocity  $v_{\downarrow k} = W \nabla \psi^* \partial_{\downarrow k} \psi / \psi^* \psi$  ( $Q_{\downarrow 1}, \dots, Q_{\downarrow N}$ ), where the **new constant** is  $W = \hbar / m_{\downarrow k}$

# Wave function?

- French (2013):
  - Within wave function realism, we still have **underdetermination**
  - We can break it if we consider the wave function as ‘constituted by the laws’
- This is fully compatible with primitivism:
  - The wave function is **nomological**
  - It can be considered as part of the structure

# Summary so far

- In my view:
  - There are **'thin' objects** individuated only by the property that specifies its nature
    - For particles, it's spatial position
  - There is **structure**: a network of relations
    - In the quantum domain they are implemented by the wave function
- Thus, we have **STRUCTURE GROUNDED IN THE PRIMITIVE ONTOLOGY**

# Why prefer my view over the **traditional view**

- 1) it is **ontologically more parsimonious**
  - [Ontology + properties + laws] < [ontology + law]
  - Similar to EOSR, but here we eliminate properties, not objects
    - → we overcome the objection to EOSR that the view is unintelligible
  - To support this parsimony: **the optimistic meta induction argument**
    - Theories that postulated less **categories** have been more successful than theories that do not

# Why prefer my view over the traditional view

- 2) it **eliminates** the debate over the **nature of properties**
  - There are no properties other than spatio-temporal properties
- 3) **contextuality** goes away:
  - If spin is a property, then it is contextual:
    - Its value depends on the measurement performed
      - →???!!!
  - In contrast, in my view spin is not a property, but a part of the law

# Why prefer my view over the traditional view

- 4) it is the **natural approach**, from an **empiricist** point of view:
  - The only things we **see** are **things that move**
    - We do not see masses, charges, or spins!

# Why prefer my view over the traditional view

- 5) it is the **natural approach**, from a **Humean** point of view:
  - It provides the **best combination of simplicity and strength**
    - It 'multiplies' effective laws in order to keep the ontology 'as simple as possible'
    - But the axioms and theorems remain the same

# Why prefer my view over the traditional view

## 6) The view is **more explanatory**

- **standard view**: to explain why particles have the mass they do
  - No mystery in my view: they follow different effective laws
- Objection!
  - The situation is the same under another name: we do not have an explanation of why the different laws exist and are followed
- Reply: not true
  - In the traditional view, we do not know:
    - why we have the **laws** we have anyway, AND
    - why particles have the **properties** they do
  - In my view we 'just' need to explain things about laws

# Why prefer my view **over EOSR**

1) The view breaks the **underdetermination**:

- The wave function evolution is **underdetermined**:
  - As long as the wave function generates the same trajectories for the PO
- But that's OK: the wave function does not represent matter
- The underdetermination regarding **objects** is broken:
  - The PO is **postulated**

2) The view accounts for **entanglement**:

- Individual entangled systems do not possess their own wave function
- But that's OK: the wave function does not represent matter

# Why prefer my view over EOSR

3) The view **avoids major objections** to EOSR:

- 3a) the view is **intelligible**:
  - There are relata (the PO)
- 3b) the view **distinguishes** between mathematical and physical structure
- 3c) the view **defeats** the PMI
  - If the wave function is considered as part of the structure

# Why prefer my view over EOSR

4) EOSR is **much more revisionary** than my view:

- EOSR has to re-construct macroscopic objects and their properties using a **top-down** approach which is all to be invented
  - Work in progress
- My view instead is **bottom-up**:
  - From the PO at the bottom, up to the macroscopic things
- And this has the advantage of being a **well-developed, established** approach
  - Method **similar** to the classical ones also in the quantum framework
    - Reductionism and compositionality

# Possible objections and replies

- 1) The view is **unnecessarily radical**
  - why do you want to get rid of properties if they work so well in the standard schema?
- Reply
  - The proposal is far from being unnecessary: properties are notoriously rough nuts to crack

# Possible objections and replies

- 2) There are **infinitely many** laws: one law for every massive object
- Reply:
  - Careful: not for every massive object, but for **every entity** that in the traditional view we take to be fundamental
  - However, there is just **one kind of material entity**, and one kind of law, implemented differently depending on what it is acting on
  - Macroscopic objects are made of the microscopic entities, and their behavior can be explained and accounted for in terms of them

# Possible objections and replies

- 3) **In virtue of what** different effective laws act on matter, if there is just one kind?
- Traditional view: the positive charge of the proton *makes it* go down rather than up
- My view: we have just matter.
- So, how is a material entity ‘**paired up**’ with its ‘effective’ law?
- Reply:
  - Traditional view: it is **a primitive fact** that positive charge will result in ‘going up’ in a given magnetic field
  - My view: it is **a primitive fact** that that ‘effective’ laws act as they do

# Possible objections and replies

- 4)  $E=mc^2$  establishes that the energy of the particle is associated to its mass. How does that fit in this approach?
- Reply:
  - We were used to think of mass as a property, but we are mistaken
  - Similarly, we were used to think of energy as a property, and we are mistaken as well

# Conclusion

- My view:
  - just **one kind of material entity** with no other fundamental property over and above its spatio-temporal ones
  - It appears *as if* there are different fundamental entities which are identified by their properties
  - Rather, there is **just one kind of law**, and **many 'effective' laws**
- This view **shares many motivations** for structuralism **without** falling pray of its **objections**
- Because of this, should be preferred

Thank you!