

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**)

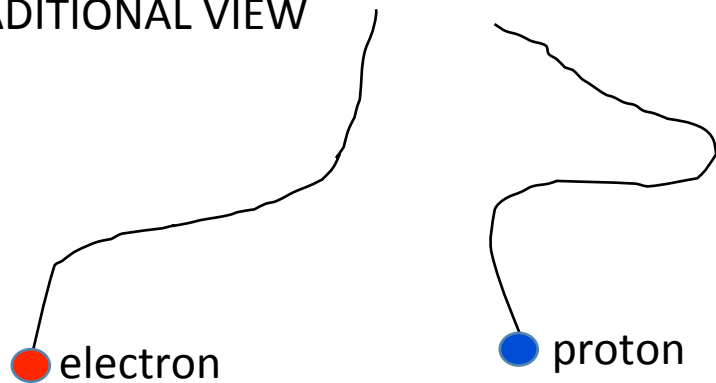
Laws

- 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

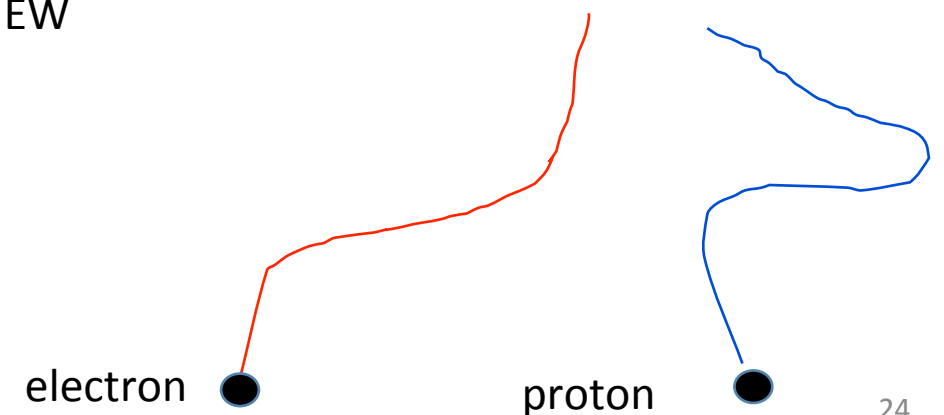
Laws

- 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 $v_{\downarrow k} = W \nabla \psi^* / \psi^* \psi$ ($Q_{\downarrow 1}, \dots, Q_{\downarrow N}$), 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!