

**Against a structural realist
understanding of spacetime:
the disanalogy between points and particles***

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What is structural realism?

Even if we are able to decide on a canonical formulation of our theory, there is the further problem of metaphysical underdetermination with respect to, for example, whether the entities postulated by a theory are individuals or not. . .

We need to recognise the failure of our best theories to determine even the most fundamental ontological characteristic of the purported entities they feature. . . What is required is a shift to a different ontological basis altogether, one for which questions of individuality simply do not arise. Perhaps we should view the individuals and nonindividuals packages, like particle and field pictures, as different *representations* of the same structure. There is an analogy here with the debate about substantivalism in general relativity.

(James Ladyman, *What is Structural Realism?*)

Outline

1. James Ladyman's *What is structural realism?*
2. Problems faced by realism, and by epistemological structural realism
3. Underdetermination
4. In favour of full-blown substantivalism
5. Back to the alleged analogy between QM particles and spacetime points
6. What's problematic about QM particles?

Structural Realism

- The best of both worlds (**Worrall**):
 - The pessimistic meta-induction (PMI)
 - the no miracles 'argument' (NMA)
- *What is Structural Realism?* (**Ladyman 1998**)
 1. Two varieties of structural realism:
 - Epistemic structural realism (ESR)
 - Ontic structural realism (OSR)
 2. Criticisms of ESR
 3. Underdetermination
 - (a) Different formulations of a theory
 - (b) 'Metaphysical underdetermination'
 4. Individuality in QM; substantivalism vs relationalism

Ladyman Against ESR

Epistemological structural realists have recently cashed out talk of knowledge only of structure in terms of a theory's **Ramsey Sentence**.

1. The Newman/English problems

- If a Ramsey sentence is empirically adequate it is true
(*cf. Putnam's Paradox*)
- Any two incompatible Ramsey sentences differ empirically

2. A Ramsey sentence 'refers' to exactly the same entities as the original theory; "If the meta-induction is a problem about lack of continuity of reference then Ramsifying a theory does not address the problem at all" (French and Ladyman 2003)

Worall and Zahar disagree. The debate goes on. . .

What is *Epistemic Structural Realism*?

- (A): We can know everything but the individuals that instantiate a definite structure; or,
- (B): We can know everything except the individuals and their first-order properties; or,
- (C): We can know everything except individuals, their first-order properties and their relations

Psillos, *Is Structural Realism Possible?*

- Compare (C) to structural realism articulated via Ramsification
- Compare (B) to Langton's 'Kantian Humility'; the intrinsic properties of *all* external objects are unknowable.
- [● Where does Lewis' *Ramseyan Humility* fit in?]

ESR, traditional realism, and (modest) structuralism

Against the Lewis/Langton version: why endorse quidditism?

By discovering more about the properties of mass, we discover more about its nature, i.e. about what mass *is*.

(Psillos 1999, p. 156)

- NB, this does *not* involve a worrying holism about *meaning*.
- An analogy with structuralism in philosophy of mathematics.

An *Ersatz* form of realism?

We need to recognise the failure of our best theories to determine even the most fundamental ontological characteristics of the purported entities they feature. It is an *ersatz* form of realism that recommends belief in the existence of entities that have such ambiguous status.

(Ladyman 1998)

French and Ladyman 2003:

- The case of 19th and 20th century atomism: ‘atoms were understood as individuals where the metaphysical nature of this individuality was typically explicated in terms of substance or, more usually in the case of physicists at least, in terms of the particles’ spatio-temporal location’
- Redhead’s questions: ‘What is a field?’ versus ‘what are the equations which govern its behaviour?’

Towards OSR: Underdetermination

Ladyman's claim: traditional realism goes beyond commitment to structure precisely in terms of metaphysical commitments that are underdetermined by the evidence for them.

- **Type 1 underdetermination:** different formulations of a theory
 1. Schrodinger's versus Heisenberg's versions of QM
 2. Newtonian gravitation: action-at-a-distance forces versus Newton-Cartan
- **Type 2 underdetermination:** 'metaphysical underdetermination'
 - Fields as substantival vs. as properties of spacetime points
 - Quantum particles as (non)individuals
 - Relationalism versus substantivalism

Taking Stock

ESR and/or traditional realism:

1. is undermined by referential discontinuity in theory change (PMI)
2. risks collapsing into full-blown empiricism (Newman problem)
3. is underdetermined by the empirical evidence

* * *

Why think that OSR fares any better?

What is it???

Ontic Structural Realism: the wish list

We regard the ontic form of SR as offering a reconceptualisation of ontology, at the most basic metaphysical level, which effects **a shift from objects to structures**. . . a form of realism adequate to the physics needs to be constructed on the basis of an alternative ontology which replaces the notion of object-as-individual/non-individual with that of structure in some form. (37)

We urge the reconceptualization of electrons, elementary particles and so forth in structural instead of individualistic [objectual?] terms. (37)

How can you have structure without (non-structural) objects? Here the structuralist finds herself hamstrung by the descriptive inadequacies of modern logic and set theory which retains the classical framework of individual objects. . . In lieu of a more appropriate framework for structuralist metaphysics, one has to resort to a kind of 'spatchcock' approach, reading the logical variables and constants as **mere placeholders which allow us to define and describe the relevant relations which bear all the ontological weight**. (41)

OSR and the Newman problem

The semantic approach to theories is supposed to hold the key. Why?

it is important to recall that with respect to the introduction of partial isomorphisms and homomorphisms, such set-theoretical relationships hold only between the mathematical structures and not between such structures and 'the world' itself (French and Ladyman 1999). The realist representation relationship between theories and the world must be sought elsewhere, perhaps in a notion of reference appropriate for a broadly structuralist metaphysics.

(2003, p. 34)

phenomena, understood presumably as something like actual physical events, cannot be put into *isomorphism* with an abstract entity, like a phase space representation of a simple harmonic oscillator, since the notion of isomorphism is defined for mathematical objects only.

(French and Ladyman 1999, p. 112)

OSR and Type 1 Underdetermination

Different formulations of a theory

- Weyl recognised that the mathematical status of the two rival theories of quantum mechanics as alternative *representations* of the same mathematical structure, makes preference for either eliminable once a unified framework is available. (Ladyman 1998, 421)
- What is the unified framework for, e.g., Barbour's geometrodynamics and the spacetime formulation of GR?

On the most straightforward understanding of structure, different formulations will involve different (though partially isomorphic) structures.

OSR and Type 2 Underdetermination

The locus of the metaphysical underdetermination is the notion of an object so one way of avoiding it would be to reconceptualise this notion entirely in structural terms. The metaphysical packages of individuality and non-individuality would then be viewed in a similar way to that of a particle and field in QFT, namely as two different (metaphysical) representations of the same structure.

(French and Ladyman 2003, 37)

1. This has yet to be shown to be more than a promissory note.
2. It might make the underdetermination worse!
3. Is it even desirable to break the underdetermination?
4. **Is the underdetermination serious?**

Time to consider the specific cases. . .

Substantivalism versus Relationalism

Substantivalism spacetime (and its point-like parts) exist; they are concrete individuals, and they are at least as ontologically basic, and as fundamental, as the material content of spacetime.

Relationalism spacetime points do not exist, at least not as primitive concrete entities; talk about spacetime is to be understood as talk about the spatiotemporal relational properties of *material* stuff.

NOT:

?**Substantivalism** the points of spacetime are individuated independently of their spatio-temporal and other (relational) properties.

?**Relationalism** spacetime points are 'non-individuals.'

What is an individual?

Teller's criteria:

Strict identity there is a fact of the matter for two putatively distinct objects that they are either distinct or that, after all, they are one and the same thing (standard set theory is applicable)

Labeling things can be referred to with names 'directly attaching' to the referents

Counterfactual switching a being A and b being B is a distinct possible case from b being A and a being B , where A and B are complete rosters of, respectively, a 's and b 's properties in the actual world.

But (Labeling) and (Counterfactual switching) are unmotivated.

Full-blown (but 'anti-haecceitist') substantivalism

1. Substantivalism is supported by a straightforward interpretation of the models of the theory ($\langle M, g \rangle$ in $\langle M, g, T \rangle$)
2. g of GR plays *precisely* the rôle of η in special relativistic theories
3. g is very unlike other fields (against Rovelli's 'relationalism')
4. Haecceitism is *not* supported by a literal reading of GR models; on an anti-haecceitist reading, GR models do *not* contain 'surplus structure'
5. Anti-haecceitism is not in conflict with space-time points being fully-fledged individuals (i.e. substantival)
6. Anti-haecceitism avoids the hole argument (but it can be independently motivated, e.g., Hofer, 1996)

An aside on a false dichotomy

- relations are ontologically 'prior' to, and 'constitute' their relata (a 'sophisticated' bundle theory, allowing some violation of the PII), versus
- Relata are ontologically prior to their properties and relations; their numerical diversity is independent of their positions in a relational network

It has long been recognized that bare particulars and bundle theory do not provide an exhaustive set of options, and that a third way is far more plausible than either.

Stachel on the hole argument

- The essence of the hole argument is preserved by abstraction by deletion (of differentiability and continuity properties)
- Covariance under diffeomorphisms becomes permutability
- For a set of elements that enter into a given ensemble of relations:
 1. the elements can be individuated “prior to and without reference to” these particular relations, or
 2. the elements can be such that they are not individuated without reference to the relations (**:= reflexively defined entities**)
- The hole argument forces us to consider spacetime points as of type (2)

Stachel on the particle/point analogy

One can immediately apply this result to the current discussion about the individuality of elementary particles. . . One group maintains that each elementary particle retains its individuality, and that quantum statistics are merely the result of the fact that certain states. . . that are accessible to systems of elementary particles that are not of the same kind, are for some reason inaccessible to systems of particles that are all of the same kind. The other group maintains that quantum statistics has its origin in the lack of individuality of elementary particles. As far as I know, no one has drawn attention to the close analogy between these positions and those of the so-called space-time substantivalists on the one hand and the relationalists on the other. Nor has anyone mentioned the possibility of extending the hole argument from the discussion of the individuality of space-time points to the discussion of the individuality of elementary particles, as I shall now do.

French and Rickles on the analogy

Stachel (2002) has recently explored the connections between the interpretation of general covariance and permutation invariance on the one hand and the metaphysical analyses of spacetime points and quantum particles on the other. He begins by abstracting the differentiability and continuity properties of the manifolds leaving a bare set of points. The (continuous) principle of diffeomorphism invariance then becomes (discrete) [!] permutation invariance. A version of the hole argument can then be seen to apply to this set. . . We have already seen how such a set, along with PI, models the statistical behaviour of ensembles of indistinguishable quantum particles. Thus the analogy is complete. . .

Understanding Permutation Symmetry

And French and Rickles underwhelmed

Stachel. . . understands the non-individuality of particles as their being individuated 'entirely in terms of the relational structures in which they are embedded'. . . But then it is not clear what metaphysical work the notion of 'non-individuality' is doing, when we have still 'objects' which are represented by standard set theory (and this is precisely the criticism that can be levelled against attempts to import non-individuality into the spacetime context). . . Of course, Stachel could still maintain individuality. . . but at the price of introducing . . . indeterminism. . .

Again the alternative, 'middle way' is to drop objects out of the ontology entirely, regarding both spacetime and particles in structural terms. Indeed, this appears to be the more appropriate way of understanding both Stachel's talk of individuating objects 'entirely in terms of relational structures in which they are embedded'. . . However, rather than thinking of objects being individuated, we suggest they should be thought of as being structurally constituted in the first place. In other words, it is relational structures which are regarded as metaphysically primary and the objects as secondary or 'emergent'.

Understanding Permutation Symmetry

Quantum statistics and individuality: I

- Two particles, a and b
- Two possible single-particle states, L and R

‘Classically’ we expect there to be four possibilities:

1. $L(a)$ and $L(b)$
2. $R(a)$ and $R(b)$
3. $L(a)$ and $R(b)$
4. $R(a)$ and $L(b)$

If these are equiprobable we get Maxwell Boltzman statistics

But we observe. . .

Quantum statistics and individuality: II

- Bose-Einstein, or
- Fermi-Dirac statistics

For example, in the Bose-Einstein case, we have:

1. $L(a)$ and $L(b)$ prob = $1/3$
2. $R(a)$ and $R(b)$ prob = $1/3$
3. $L(a)$ and $R(b)$ \updownarrow prob = $1/3$
4. $R(a)$ and $L(b)$ \updownarrow

- Particles are 'non-individuals' \Rightarrow (3) and (4) are not distinct states (The 'Received View', e.g., Redhead and Teller 1992).
- (3) and (4) are distinct states, but they're not accessible/preparable (French and Redhead 1988).

Back to Stachel

quantum-mechanical statistics imposes the requirement that all physical relations between them be permutable. Our set theoretical hole argument shows that, if we ascribe an individuality to the particles that is independent of the ensemble of permutable relations, then no model can be uniquely specified by giving all the n -place relations \mathbf{R} between them unless we further specify *which* particle occupies *each* place in these relations. . .

The points of spacetime are characterized as such. . . independently of the particular relations in which they stand to each other; but they are *entirely* individuated in terms of the relational structure given by some fibred manifold. . . electrons may be characterized as a kind in a way that is independent of the relational structure in which they are imbricated, but a particular electron (or group of electrons) in an atom, for example, can only be individuated by its role in such an atomic structure. **Consequently, all relations between N of these particles must be invariant under the permutation group acting on these particles.** (My emphasis)

The disanalogies

- We do not simply legislate that $L(a)R(b)$ and $R(a)L(b)$ are to be regarded as representing the same state, we disallow *both* and instead have only $(L(a)R(b) \pm R(a)L(b))$
- This is more radical than (modal) anti-haecceitism, it *enforces* violation of the PII (a contrast with the spacetime case)
- It therefore becomes hard to regard the 'labels' ' a ' and ' b ' as referring to individual particles (Teller); (a certain variant of the 'particles as individuals' view is under pressure)
- There are alternative formulations: Fock Space, and doing QM on the reduced configuration space. (What are the analogues for spacetime?)

The problem of identical particles

- The disanalogies suggest that the peculiarities of QM particles are not just to do with anti-haecceitism
- In any case, the anti-haecceitist *can* derive Maxwell-Boltzmann statistics (Huggett, *Atomic Metaphysics*)
- Particles persist. We therefore have questions of identity over time to consider, not just across possible worlds.
- The 'haecceitist' phase space of classical statistical mechanics might simply encode transtemporal distinctions, not haecceitistic differences.
- Is the origin of quantum statistics quantization (*cf.* Huggett), or lack of transtemporal identity (*cf.* Reichenbach)?
- *Pace* Stachel, quantum particles cannot be thought of as individuated in terms of their properties and relations *even at a single time*: the particle stage that is in the left wing of the apparatus cannot be identified with the spin-up particle.

Finally, ontic structural realism again

the following objection has been raised. . . if structure is understood in 'relational' terms. . . then there need to be 'relata'. . . How can PI play a part in the 'deconstruction' of objects into structures when its very articulation is based on the assumption that there are objects to begin with?. . . [W]e recall that we begin by introducing particle labels and it is upon these particle labels that the particle permutation operator acts. We then assume that these labels denote objects. . . and this allows us to apply the mathematics of group theory (with its underlying standard set theory). However, once we have obtained the relevant structure, we can dispense with our original assumption, regarding it as no more than a heuristic crutch and the labels as convenient place-holders which serve only to help us focus attention on what is metaphysically fundamental – PI in this case. . . The object is a kind of 'ladder' which we use to reach the structure but which we can then 'throw away'

(French and Rickles)