Structural realism · J.P. Loo
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I have set this handout a little austerely to save paper. A mobile-friendly version is available on request.

1 Preliminaries. This section is particularly potted, but should make explicit the background picture in my mind, which may help in the formulations of questions and objections.

1.1 Realism… A rough background view that is fairly widely considered plausible: science is successful; we should take its findings seriously; use of the scientific method is rational; science is *true* (how?); and so on.

Such a view isn't wholly uncontested, but, I claim, is a fairly typical part of the sort of worldview of those who seek to vindicate scientific realism.

Thus Putnam, somewhat elusively: only realism 'doesn't make the success of science a miracle' [PUT75: 73].

1.2 …and its discontents.

1.2.1 Science changes. This is a problem for completely unbridled commitment to science on pain of inconsistency and/or exclusion of enough science to avoid inconsistency.

1.2.2 Tempering realism. Perhaps science converges on truth; and, perhaps, it is approximately true.

In both cases we are *partially* committed to theories but not wholly.

1.2.3 Laudan: referential success is not a good criterion in choosing theories and susceptible to a pessimistic metaïnduction; convergent realism is reliant on overly weak notions of 'limiting case'; and so on.

1.3 Structural realism.

1.3.1 Worrall.

— Worrall proposes on the move from Fresnel to Maxwell not the 'carrying over… [of] empirical content', and not 'the full theoretical content or full theoretical mechanisms (even in "approximate" form)', but continuity of '*form* or *structure*'.

— It remains somewhat obscure in Worrall what that structure is, but Worrall mentions '*formally* similar laws' [WOR89: 118].

— The simplest such example is given by the following equations, which supposedly gave the vibration of elastic: this of course is wrong in Maxwell's theory, but if the variables are reinterpreted to concern the electric and magnetic fields, then the equations are completely right [WOR89: 119].

— Of course, the equations change too, but at that level, growth is 'cumulative', even though at the ontological level 'radical replacement' is typical.

1.3.2 Chakravartty's distinction between ESR and OSR (epistemic and ontic structural realism resp.) [CHA04: § 1].

— ESR: 'we can know structural aspects of reality, but nothing about the natures of those things whose relations define structures in the first place'.

— OSR: 'do away with objects'; we can only know structural aspects of reality because that is all there is to it.

1.3.3 Ainsworth's further distinctions. The central claim of OSR, to Ainsworth, is 'denial that objects and/or properties are ontologically primitive' [AIN10: § 1], suggesting three positions [AIN10: Table 1]: denial of ontological primitivity

OSR1 to both,

OSR2 properties only, and

OSR3 objects only.

We also distinguish *eliminativism*: the view that 'there are no individuals (but there is relational structure)'.

1.3.4 Two sorts of considerations. The motive for structural realism we have seen is largely epistemic; it has implications for the metaphysics of our theories, of course.

But there are independent arguments for OSR based on modern physics; this is the focus of Ainsworth [AIN10].

2 Metaphysical arguments for OSR.

2.1 The underdetermination argument for OSR1 [AIN10: § 2].

2.1.1 The very idea.

P1 If its ontology is of objects, properties, and relations, physics does not settle whether those objects are individuals or non-individuals.

P2 But it does settle whether those objects are individuals or non-individuals if we strip out the objects and properties.

P3 We should avoid underdetermination if possible.

C Therefore, we should take the ontology of quantum (and all?) physics to only be of relations.

2.1.2 P1. Classically, given two states and two particles, there are four possible microstates: $|S_1>_1 |S_1>_2; |S_2>_1 |S_2>_2; |S_1>_1 |S_2>_2$; or $S_2>_1 |S_2>_2$

But in quantum mechanics, we have $|S_1>_1 |S_1>_2; |S_2>_1 |S_2>_2; \frac{1}{\sqrt{2}}(|S_1>_1 |S_2>_{2^+} + |S_2>_1 |S_1>_2)$; or $^1/\sqrt{2}(|S_1>_1 |S_2>_{2^-} - |S_2>_1 |S_1>_2)$.

— Symmetric states can be written $c(|S_n>_1 |S_m>_2 + |S_n>1|S_m>2$; the first two classical and three quantum microstates above are symmetric. The minus sign gives antisymmetry; the last quantum microstates is anti-symmetric.

— Both types are permutation invariant in the sense that exchanging particle labels leaves the states unchanged (up to sign.)

— French et al. suggest that quantum particles can be regarded as permutation-invariant individuals.

— There is a slightly compressed argument that this is 'not a serious contender' following Pooley, since 'permutation invariance must be taken as a primitive state accessibility restriction' which seems rather *ad hoc*. (At least, that is how I read the argument.)

— *Remark.* Would anybody care to elaborate?

2.1.3 P2.

— *Non-eliminative* OSR1 doesn't seem to help much because there are still underdetermined individuals.

— *Eliminative* OSR1 doesn't seem to make much sense either. Quantum mechanics even deflationarily interpreted attributes properties to objects; or, at least, it keeps properties about.

2.2 *The entanglement argument for* OSR2 [AIN10: § 3.1].

2.2.1 *Bipartite quantum systems* are entangled states iff they can't be written as the product of two separate states.

2.2.2 'Entangled quantum particles appear to have relations to other quantum particles, but no properties.'

2.2.3 *Response.* Entangled particles have state-independent properties. Trying to avoid this is unmotivated and likely difficult because Hamiltonian operators 'always dependent on state-independnet properties'.

2.2.4 *Response.* Not everything is entangled.

2.2.5 *Response.* Entangled particles don't readily appear to have relations to each other.

2.3 *The argument for* OSR2 *from non-knowledge of properties* [AIN10: § 3.2].

2.3.1 A one-place predicate used could be a disjunction of several natural properties 'exactly alike in the causal relations they enter into'.

2.3.2 The claim is that we don't have knowledge of properties and therefore we should prefer a metaphysics without them.

2.3.3 But it seems we *do* have knowledge of them, if limited.

2.4 *The substantivalist argument for* OSR2 [AIN10: § 3.3].

2.4.1 *Substantivalism motivated.* The de Sitter solution to the field equations of GR leaves space-time empty, so we might not want space-time to be ontologically secondary to matter; and we construct models of the field equations with a manifold of space-time points.

2.4.2 *Diffeomorphism problems.* Given a model $\langle M, g, T \rangle$ there are infinitely many novel models via the infinitely many autodiffeomorphisms on M; these vary by the points in M underlying parts of fields.

2.4.3 *Non-individualism.* We could treat space-time points as non-individuals, in which case their permutation is unintelligible. This coheres well with noneliminativist OSR1 (perhaps).

2.4.4 *Non-unique isomorphisms.* If there is more than one isomorphism between two models the isomorphisms don't tell us which points to identify. But perhaps we shouldn't assume that it 'must always be possible uniquely to decide which object in a given structure is to be identified with which in another (isomorphic) structure'.

2.4.5 *Esfeld and Lam*: OSR2 puts relations and objects on 'the same ontological footing' and in conceptual interdependence, so 'it makes no sense to talk about space-time points independently of the relations in which they stand to one another'.

2.4.6 *Response.* It does not follow that properties do not exist.

2.4.7 *Response.* Even if we can do so in GR, can we in QM?

2.5 OSR3 *and neoclassical ontology.*

2.5.1 OSR3 appears to be motivated by difficulties in identifying individuals.

2.5.2 *Neoclassical ontology* simply denies individuality but retains the ontological primitivity of objects, properties, and relations.

2.5.3 osr3 is more parsimonious; but it does make formal semantics hard.

2.6 *Chakravartty against undeterdetermination arguments*: 'What is the significance of underdetermination?...[it is] suggestive at best' [cha04: § 4].

2.6.1 *Underdetermination arguments mostly concern quantum phenomena*—but why would that 'infect the status of objects at non-quantum levels of description'? We'd need an (as yet absent?) reductionist argument.

2.6.2 *Ersatzness* is too hastily assumed to follow from underdetermination. Physics underdetermines the choice between 'bare substrata instantiating properties and bundle theory', both of which 'are associated with well-known problems'—but that does not lead to renunciation of the idea of macroscopic objects [cha04: 159].

French and Ladyman argue that macroscopic objects can be 'experienced "directly" and identified ostensively', unlike 'unavoidably theoretical' quantum unobservable objects. It is in the latter case that undeterdetermination is a problem.

2.6.3 *Remark.* At least to me there's a distinction between the metaphysical undeterdetermination to which Chakravartty adverts and the underdetermination of French and Ladyman's argument.

— In the former case *which objects there are* is determined, and we are merely quibbling about objecthood.

— In the latter case, which objects there are is underdetermined, even before we ask in what objecthood consists.

— Arguably the latter is more serious; for it is quite common to give philosophical accounts in terms of slightly problematic or not wholly elucidated concepts, *e.g.* knowledge, causality, and time.

Rather, the central question to ask is: what are the relata?

3 Metaïnductions.

3.1 *Background.* Recall Laudan's list of successful but non-referential theories. There are (at least) two ways of dealing with such arguments (Psillos: *divide et impera*).

3.1.1 *Divide*: throw out some of the theories.

3.1.2 *Impera*: what do we say about the remaining theories?

3.2 *Answer: internally divide theories*—'separate aspects of theories most worthy of belief from those for which we have less warrant' [cha04: 161].

Then a *pessimistic* metaïnduction goes through on science *simpliciter*, but an optimistic one goes through on the isolated parts of the theories.

3.3 *Which parts?* The structuralist says: structure. But what does that mean?

3.3.1 *Russell*: structure is isomorphism up to order. This invites the Newman cardinality objection [see *i.a.* bwh18: cap 3]: attribution of structure turns out in the Russelian mode only to be attribution of cardinality, 'for any collection of elements can be arranged so as to exemplify a given structure so long as there are enough of them'.

This may or may not extend to other forms of structural realism [cha11: 154]; Chakravartty has a different proposal.

3.3.2 *First- and higher-order properties.*

— Russelian structure is a 'property *of* relations' [cha11: 153]. We cannot infer anything about the first-order properties or relations of objects from higher-order properties.

— Chakravartty's first-order structure is 'concrete': it 'consists in a relation between first order properties of things in the natural world' [cha11: 155].

'An identity of concrete structure requires that the elements of the sets in question...as well as the relations R and S are of the same kind, i.e. the respective elements instantiate the same relations between the same first order properties' [*loc. cit.*].

3.3.3 *An epistemic distinction.*

— *Detection properties* are 'causal properties that we have managed to detect; they are causally linked to the regular behaviours of our detectors'.

— *Auxiliary properties* are 'any other putative properties attributed to entities by theories.'

3.3.4 *The structuralist's advice to the realist* is then to 'believe in the relations of detection properties and treat anything that exceeds these structures with caution' [cha04: 163].

3.3.5 *What's special about detection properties?* First, we need them to interpret the formalism used to describe detectors, and it is to 'these structures...we have the closest epistemic access' [cha04: 163]. As theories improve, therefore, it is here that the least revision should be expected.

Moreover, certain structures involving detection properties are necessary to retain 'the ability to make decent predictions [cha04: 164]. For example, something like Maxwell's equations will be needed to ensure that the speed of electromagnetic radiation is c.

We can call this sort of interpretation 'minimal'.

3.3.6 Is minimal interpretation prospectively possible? Post hoc identification of the parts of theories to which we are committed may not give good grounds to identify the parts of present theories to which to be committed [CHA04: 165].

— Chakravartty seems to repeat the argument above: the minimal interpretations are the *sine qua non* of the respective theories, so have the 'greatest epistemic warrant'.

— That is one half of the explanation. The other half is to explain how to *prospectively* identify those parts. Chakravarrty gives a few worked examples, and then points out that Fresnel's equations were 'ultimately accepted as part of Maxwell's theory'.

— *Remark.* The latter example was presumably not wholly prospective in that the identification of the parts to be retained was simultaneous with theory change.

3.3.7 Is reference trivialised?

— Since we refine theoretical descriptions but refer to the same structures, reference isn't fixed 'purely by description' [CHA04: 166].

— Therefore the right account of reference must have some causal element. But if we 'assign the referents of terms vague enough causal roles', error could be made impossible.

— In practice, the structuralist needn't give such vague rôles: 'give the benefit of the doubt in cases not just where general causal roles are retained, but where quite specific dispositions for relations conferred by particular causal properties are preserved'.

For example, we can distinguish oxygen and phlogiston: 'oxygen has a fixed chemical composition, but dephlogisticated air *ex hypothesi* does not. Different combinations of gases may lack phlogiston and different combinations have radically different dispositions.'

4 Some loose ends and half-baked thoughts.

4.1 Can Ainsworth and Chakravartty get along? I think so: I don't think that neoclassical ontology is incompatible with Chakravartty's structural realism.

4.2 From Worrall to Chakravartty, it's not clear whether the mathematical impetus Worrall had is really maintained. That's not obviously a problem but it is curious that the position changes that much (if it does.)

4.3 Can we formalise structural *equivalence?* Chakravartty suggests not. But is that a problem?

4.4 Can we even guarantee isomorphism? Even in mathematics this is quite hard [HAM12]. If isomorphism is a necessary condition on structural equivalence, this would appear to pose a problem. (Field I think claims that set theory is conservative in *Science without numbers*, which suggests that there is enough mathematical structure in physics to lead to such problems.)

References.

[AIN10] Peter Mark Ainsworth. 'What Is Ontic Structural Realism?' In: *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 41.1 (1st Jan. 2010), 50–57. ISSN: 1355-2198. DOI: 10.1016/J.SHPSB.2009.11.001.

[BWH18] Tim Button, Sean Walsh and Wilfrid Hodges. *Philosophy and Model Theory*. Oxford: Oxford University Press, 2018. 517 pp. ISBN: 978-0-19-879040-2.

[CHA04] Anjan Chakravartty. 'Structuralism as a Form of Scientific Realism'. In: *International Studies in the Philosophy of Science* 18.2-3 (1st July 2004), 151–171. ISSN: 0269-8595. DOI: 10.1080/0269859042000296503.

[CHA11] Anjan Chakravartty. *Scientific Realism*. In: *Stanford Encyclopedia of Philosophy*. 27th Apr. 2011. URL: HTTPS://PLATO.STANFORD.EDU/ENTRIES/SCIENTIFIC-REALISM/#ThreDimeRealComm.

[HAM12] Joel David Hamkins. 'The Set-Theoretic Multiverse'. In: *The Review of Symbolic Logic* 5.3 (Sept. 2012), 416–449. ISSN: 1755-0203, 1755-0211. DOI: 10.1017/S1755020311000359. arXiv: 1108.4223 [math].

[PUT75] Hilary Putnam. *Mathematics, Matter and Method*. Vol. 1. Philosophical Papers. London, New York, and Melbourne: Cambridge University Press, 1975. 328 pp. ISBN: 0-521-20665-0.

[WOR89] John Worrall. 'Structural Realism: The Best of Both Worlds?' In: *Dialectica* 43.1/2 (1989), 99–124. ISSN: 0012-2017. JSTOR: 42970613. URL: HTTPS://WWW.JSTOR.ORG/STABLE/42970613.