Structure as a Weapon of the Realist by Steven French

Too long; Didn't read

I. There are well-known arguments against standard scientific realism. Object-oriented realism (OOR) arose as a response to these challenges, but it has major failings of its own. In particular, OOR cannot account for theory change, nor for the fact that modern physics has forced us to rethink our understanding of "objects." Structural realism in turn avoids the failings of OOR.

II. Worrall's Epistemic Structural Realism (ESR) attempts to accommodate theory change. In ESR, structure is manifest in the equations which are retained through theory change. A few examples from physics show that this is not enough. The structuralist must also take into account the relevant properties and relations that are preserved, and the roles they play in those theories.

III. Quantum physics renders a metaphysics of individual objects problematic. Ladyman's Ontic Structural Realism (OSR) side-steps this problem by reconceptualizing objects as aspects of an underlying structure. This structure is multi-layered and consists of webs of relations tied together by symmetry principles. Criticisms of OSR rely on its likeness to mathematical structuralism; OSR stands up to this criticism and is a promising way forward.

IV. Mathematical structuralism— Shapiro's pattern structuralism in particular— is an appropriate comparator to physical structuralism (OSR). There are two forms: *ante rem* (structures exist independently of systems) and *in re* (systems are ontologically prior to structures). Psillos launches an argument against OSR based on these two forms, but the resulting dilemma does not actually exist; the comparison with mathematical structuralism is misleading.

V-VI. Chakravartty and Psillos argue that an object-oriented metaphysics is required in order to account for:

i. The individuality of "instances of structure" that show up in the laboratory.
ii. Any explanation of change
iii. Causality and persistence
iv. The bundling together of particular properties

They are incorrect. Not only can the structuralist can account for these items as well as the object-oriented realist; she can do so more satisfactorily than the object-oriented realists (with fewer obscure primitives.)

Gems

1. "Heuristic plasticity of mathematics" p.171
2. "Theoretical baptism" p. 178

3. Fresnel-Maxwell example (Saatsi paper)

Response and questions

1. Overall, I find this paper compelling. At first I resisted French's argument, but the more digging I do, the more I agree with the structuralist approach v. object-oriented.
2. This paper would have been stronger if the physical examples were discussed in more detail with relevant equations. An explicit example is more convincing than vague mentions of "symmetry principles" in quantum mechanics.
3. French really goes into the weeds in sections **V** and **VI**. I want to ask you all what you think of French's defense of structuralism in the face of object-oriented objections. Do you take his side?

Relevant examples from physics

1. The Ehrenfest Principle (classical to quantum transition)
2. Lorentz factor in special relativity (classical to relativistic transition)
3. Indistinguishable particles in quantum mechanics (etc….)
    a. Fermionic and bosonic wavefunctions
    b. Fock states and coherent states

More to think about….

4. Noether currents in Quantum Field Theory; symmetries lead to conservation laws
5. Everettian quantum mechanics; decoherence and branching

1. The Ehrenfest Theorem:

Classical mechanics: Poisson bracket and classical equation of motion

$$\{A, B\}_{pb} \equiv \frac{\partial A}{\partial q}\frac{\partial B}{\partial p} - \frac{\partial A}{\partial p}\frac{\partial B}{\partial q} \qquad \frac{dA}{dt} = \frac{\partial A}{\partial t} + \{A, H\}_{pb}$$

Quantum mechanics: Commutator and Heisenberg equation of motion

$$[A, B] \equiv AB - BA \qquad \frac{d\langle A\rangle}{dt} = \langle\frac{\partial A}{\partial t}\rangle + \frac{1}{i\hbar}[A, H]$$

Both operations have the same algebraic properties. Both can be used in the Hamiltonian formulation to obtain equations of motion for target systems.

Moving between quantum mechanics and classical mechanics

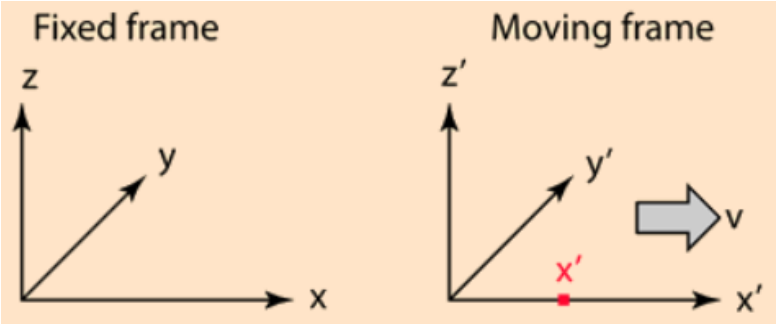
In practice: take "classical limit" $\hbar \to 0$ to move from Heisenberg to classical equation of motion

Ehrenfest theorem: the expectation values of quantum mechanical observables follow the laws of classical mechanics when the classical equations are linear.

2. Lorentz factor in Special Relativity:

$$\gamma = \frac{1}{\sqrt{1 - (v/c)^2}}$$

where *v* is the relative velocity between two inertial frames and *c* is the speed of light.



Move from *x* frame to *x'*

Lorentz transformation: Lorentz "boost"

$$x' = \gamma(x - vt) \quad y' = y \quad z' = z \quad t' = \gamma(t - \frac{vx}{c^2})$$

Galilean transformation:

$$x' = x - vt \quad y' = y \quad z' = z \quad t' = t$$

Moving between special relativity and classical mechanics

Low-velocity limit of the Lorentz factor: $v \ll c \ \rightarrow \gamma \approx 1$

Lorentz transformation reduces to the Galilean transformation. SR therefore accounts for our classical observations at small, non-relativistic velocities.

3. Indistinguishable particles in quantum mechanics

a. Fermionic and bosonic wavefunctions

Two-particle wavefunction: $\psi_{\pm}(x_1, x_2) = \psi_a(x_1)\psi_b(x_2) \pm \psi_b(x_1)\psi_a(x_2)$

Exchange operator: $\widehat{\mathrm{P}}\psi(x_1, x_2) = \psi(x_2, x_1)$

Bosons (symmetric): $\psi(x_1, x_2) = \psi(x_2, x_1) \rightarrow \ \widehat{\mathrm{P}}\psi = \psi$

Fermions (antisymmetric): $\psi(x_1, x_2) = -\psi(x_2, x_1) \rightarrow \ \widehat{\mathrm{P}}\psi = -\psi$

b. Fock states and coherent states

Fock states: states with a well-defined number of particles; eigenstates of the number operator. Eigenvalues are particle numbers. **Think: photons**

Coherent states: minimum uncertainty wavepackets; eigenstates of the annihilation operator (harmonic oscillator). Have undefined particle number. **Think: classical light waves**

Outline

I. Introduction.

- ❖ Challenges to standard scientific realism
- ❖ Standard response to challenges: Object-oriented realism (Psillos)
  - (a) Only take as referring those terms which play an appropriate role in a theory's empirical success
  - (b) Theory of reference in the form of a causal-descriptive account
  - (c) Reference to individual objects and their properties
- ❖ Two problems with OOR:
  1. OOR has trouble accommodating theory change; and
  2. Modern physics has challenged our notion of individual objects
- ❖ Solution: a shift in focus away from objects and toward structure
  - o Structure as what is carried over through theory change
  - o Structure as that in terms of which physical objects can be reconceptualized

II. Motivation One: Theory Change

- ❖ Worrall's Epistemic Structural Realism (ESR):
  - o A response to theory change: identification and representation of structural commonalities between theories
  - o Structure manifests as equations which are retained through theory change
  - o Hidden metaphysical/ontological natures
- ❖ **Example from physics: Poisson brackets; classical→ quantum transition**
  "fundamental structural features of classical dynamics are isolated, entrenched and thereby preserved in subsequent developments"
- ❖ **Example from physics: changing theories of the electron**
  "certain properties assigned to the electron […] played a crucial role in this prediction but were not represented by the appropriate equations"
- ❖ **Example from physics: Fresnel equations**
  "those features of theories which explain their success dan be identified in a metaphysically minimal manner with the theoretical properties, such as spin, charge, etc."

- Verdict: **The structural realist needs to do more than simply cite equations to accommodate for theory change.** She must also look carefully at the relevant properties and relations and the role they play in those theories. ESR isn't enough.

III. Motivation Two: Quantum Physics.

- Ladyman's Ontic Structural Realism (OSR):
  - A response to implications of quantum physics, i.e. the metaphysical underdetermination whereby physics can support two ontological views of particles; as individuals or as non-individuals
  - We can side-step the underdetermination by reconceptualizing objects as aspects of an underlying structure
  - Properties will be group-theoretic invariants described in terms of the relevant symmetry principles
- **Physics example: fermionic wavefunction**
- Multi-layered structure involving webs of relations.
  - The webs of relations are represented by the relevant laws and are tied together by higher-order symmetry principles.
  - These structures are modal (formal, mathematical); the involvement of physical properties such as spin, mass and charge must be explained
  - Objects are reduced to mere "nodes" of the structure. The "hidden natures" of ESR are eliminated.
- Invites comparison with mathematical structuralism. This comparison is misleading.

IV. Mathematical Structuralism and Physical Structuralism.

- Shapiro's Pattern Structuralism
  - *Ante rem*: Structures are freestanding and abstract; they exist independently of systems
  - *In re*: Structures are not freestanding; systems are ontologically prior and a structure is understood in terms of *any* system or *all* systems structured in that way.
- Objection from Psillos

- Objects are required! Physical objects typically possess properties not captured within the given structure.

❖ Dilemma: Natural physical systems must capture the natural relations among the objects of a system
- *Ante rem* structures play no causal role, so they cannot do this
- An *in re* structure can do this, but namely, choosing "the right" structure requires a non-structural element

❖ Solution: physical structuralism is not mathematical structuralism
- "The central claim of OSR is that it is the structure that is both (ultimately) ontically prior and also concrete"

V. Change of Ontological Framework.

❖ Chakravartty's objection: Objects are required!
- The structuralist must account for the individuality of instances of structure that show up in the lab

❖ **What metaphysics can we adopt in the quantum domain?** Given underdetermination, any importation of a metaphysics of individuality is problematic
- Solution: pseudo-individuality

❖ How pseudo-individuality works:
- Use a group-theoretical mathematical structure to accommodate the spatio-temporal location of particles
- A symmetry group will "particularize" observable quantities such as position

❖ Ladyman has argued that phenomena are non-structural; if we properly understand pseudo-individuality, particular events can be folded into the structure.

VI. Metaphysics and Causality.

❖ Chakravartty argues that objects are central to any **explanation of change**.
- Without objects we are left with explanatory gaps between subsequent states of affairs

❖ **What is it that supplies objects with the active principle of change?**
- If objects are conceived of as substance + properties, placing the active principle within the substance is just as mysterious as placing it in a structure

- It is more plausible that the active principle is associated with relations and properties; perhaps it is a property of properties

- **Causal concerns** (Psillos): causation involves a notion of structure persistence, but everyday experience tells us that there are causal changes which don't involve the persistence of structure. **Persistence** cannot be purely structural. Objects are required!
- **How does OSR account for causation? Is persistence required?**
  - OSR does not require persistence to account for causation
  - OSR "piggybacks off of the physicalist's reduction of such processes in terms of ultimately quantum processes and then insists the latter must be understood in structuralist terms"
  - Psillos is begging the question by insisting that objects are necessary.
- Chakravartty: certain groups of properties tend to cohere or **bundle**- objects required!
  - e.g. mass, spin, and charge of electron
- **What is it that accounts for the bundling together of properties?**
  - Principle of compresence; objects have no advantage over the structuralist picture
  - The structuralist can argue that aspects of different structures are "tied together"
- **Verdict**: objects don't strengthen the realist case at all; structuralism is the best tool available to defend realism.