Identity in Physics: A Historical, Philosophical, and Formal Analysis
STEVEN FRENCH AND DÉCIO KRAUSE
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Jointly, separately, and in collaboration with others, Steven French and Décio Krause have been central to recent debates about identity and individuality in modern physics; their new book draws together many threads, and is interesting in all sorts of ways. It's not an easy read, because it ranges wide and digs deep: you'll need some knowledge of physics to get anywhere, you'll need an idea of Who Was Who amongst the Great Physicists to follow the historical sections, and you'll need plenty of formal know-how to get the most out of the chapters on set theory and logic. But even if you're not fully-equipped for all this, it is well worth persisting conscientiously, skimming, or cherry-picking, according to your temperament. The book contains valuable insights into the philosophy of quantum physics; the metaphysics of spacetime; the metaphysics, epistemology and semantics of identity, indiscernibility and naming; the logic of indeterminacy; and the nature of sortals. There are thought-provoking methodological asides about the relationships between science and philosophy, between formal theory and interpretation, and between set theory and contingent facts. Moreover, the historical sections show the Great Physicists grappling with these substantive philosophical issues. (Tip: if you're only going to read one chapter, make it chapter 4, where the philosophical juice is especially concentrated.)

The central question is whether fundamental entities of various sorts are individuals. If so, what, if anything, grounds this individuality? If not, what implications does this have for naming, logic, and set theory? The central question makes sense only if we can grasp how something could fail to be an individual. Nonindividuals are not nonparticulars, i.e. universals; instead, they are entities which somehow undermine our practices of identification, reidentification or counting. They may 'lack self-identity'; the idea is not that each is distinct from itself, but that the notions of identity and distinctness do not apply to them. A number of issues collide here; one of French and Krause's achievements is to have unpicked the ways in which different aspects of nonindividuality have been elided or distinguished by physicists and philosophers working in this field.

A first issue arises from indiscernibility: modern physics commits us to all sorts of intrinsically indiscernible entities. This is partly because, as it turns out, there are relatively few determinable intrinsics (e.g. mass, charge, spin) and partly because fundamental entities exemplify only a few determinate values of those determinables (e.g. all electrons have the same negative charge). The extent of absolute (intrinsic *and* extrinsic) indiscernibility is more disputed, but does seem to take in spacetime points and suitably-entangled bosons, at least. If there are indiscernible entities, we may ask what grounds their distinctness – in virtue of what are they distinct rather than identical? If the entities cannot be distinguished qualitatively or spatiotemporally, then, suggest French and Krause, their distinctness must be

'transcendental'. That is, either their distinctness is brute or else it is grounded in 'primitive thisness' or Lockean substratum.

A second issue arises from the fact that, when quantum particles become entangled with one another, their collective state is irreducible to their separate, intrinsic states. This places ontological weight onto the relations between such particles, at the expense of the particles considered separately, and is responsible for the holistic, non-local aspect of quantum reality; moreover it makes the threat of absolute indiscernibility more powerful.

A third issue arises out of statistical physics. Does it make a difference to the behaviour of an aggregate of particles which particular particle is in which state? In one sense, no: if you switched all the particles around, the aggregate would look just the same. But in another sense, yes: classically, aggregative states which can be realised by many different permutations of particles (e.g. half in box A, half in box B) occur more frequently than those which cannot (e.g. all in box A). Quantum statistics, however, tell a different story: for some types of particle, some aggregative properties are simply impossible (e.g. no aggregates of fermions in which they're all in the same state), and amongst the possible aggregative properties, no extra weighting is given to those which, intuitively, are multiply-realisable. One explanation of this is that the particles involved are 'nonindividuals' and so the relevant states are not in fact multiply-realisable; an alternative (rather ad hoc) explanation is that each realisation of a multiply-realisable state is inherently, and proportionately, less probable than a realisation of a singly-realisable state.

These three concerns – indiscernibility, entanglement, permutation-insensitivity – all speak against our pre-scientific picture of objecthood, but it is far from clear that they speak with one voice. I am less concerned than French and Krause are about the threat of indiscernibility: Heinz Post's 'transcendental individuality' may sound like personalised yoga tuition, but if it is merely a matter of brute identity facts, then this seems as good a place as any for explanations to run out. Similarly, entanglement, though physically surprising, doesn't seem metaphysically intractable: why should we have expected relations always to reduce to intrinsic properties?

It is harder to dismiss the quantum statistics, however, which really do seem to challenge the classical foundations of our everyday (and *a priori* metaphysical) way of thinking about the world. French and Krause's discussion is subtle and complex, but a key conclusion is this: we can do some fancy footwork about initial probability distributions, 'supra-empirical structure', or inaccessible states, in order to retain a fairly familiar view of objects, or we can accept the Received (amongst the cognoscenti) View, according to which we should avoid all the fancy footwork by accepting that quantum objects are nonindividuals.

Before reading *Identity in Physics*, I found this talk of 'nonindividuals' deeply puzzling, and even suspected it of incoherence. I can report that my puzzlement has not been completely eradicated, but that it is certainly reduced. There were two main sources of my puzzlement. First, there is the concern that talk of 'nonindividuals' is shorthand for talk of 'entities which behave, collectively, in accordance with the quantum statistics'; clearly, we need to go beyond this if we seek to explain the statistics. More seriously, there's the concern that if quantum particles turn out to be

'nonindividuals', we'd do better simply to admit that they do not exist, that our ontology should be one of fields, or aggregates, or states, or structures, or whatever else does the job. If this concern is not mere prejudice, then it is driven, I think, by a Quinean conception of ontological commitment: if the usual apparatus of quantification (including the logic of identity) does not apply to these so-called objects, then we don't have good reason to believe in them. Non-self-identical entities, indeed!

Both these concerns may be addressed by French and Krause's development of quasi-set theory – a formal framework for talk of nonindividuals and collections of nonindividuals – and Schrödinger logics. Standard set theory, by giving an extensional characterisation of sets, presupposes that there are identity facts for the Urelemente. This presupposition is undermined if quantum nonindividuals may join set-like collections; quasi-set theory allows for both individual and nonindividual Urelemente. Relatedly, Schrödinger logics do not contain $\forall x(x=x)$ as a generally valid law. I am not qualified to assess this work, but it does at least promise both to substantiate the notion of a nonindividual and to provide an alternative to standard ideas of ontological commitment.

Despite their valiant efforts to substantiate the nonindividuals view, French and Krause remain agnostic about whether we should accept nonindividuals, or else pay the ideological price for an exclusively individuals-based ontology. This illustrates one of their overarching themes: physical theories rarely supply straightforward answers to metaphysical questions, and metaphysics is typically underdetermined by physics (much as physical theory is often said to be underdetermined by empirical data). This claim is ripe for further exploration, given the detailed attention which has been paid to underdetermination in the philosophy of science literature: individuals-physics and nonindividuals-physics may be two genuine rivals, unlike the toy examples we sometimes discuss (and physicists' attitudes here might provide interesting studies for van Fraassen's distinction between belief and acceptance). The existence of rival mathematics and logics accompanying the rival (meta)physics raises further intriguing questions about whether we can judge the alternatives by commensurable standards.

In short, then, *Identity in Physics* is a very significant contribution to debate about, well, identity in physics, but it deserves attention from general philosophers of science and metaphysicians too.

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