Book Review

Identity in Physics: A Historical, Philosophical and Formal Analysis

Steven French and Décio Krause
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The development of quantum physics has undermined some of the main assumptions on which both classical physics and the contemporary commonsense view of the world rest.

In this book, the effort of the authors is primarily devoted to the analysis of some metaphysical/ontological issues raised by contemporary physics, and in particular they investigate the relation between three main notions: *individuality*, *distinguishability*, and *trans-temporal identity*. Such an investigation, that is primarily of a philosophical kind, is carried forward by coordinating both philosophical and historical issues, and it ends up with the proposal of a logical system that results appropriate for the formalization of both quantum and non-quantum objects.

The central problem concerns the impact of quantum theory on the classical metaphysical theory of identity, based on Leibniz's 'Principle of the Identity of Indiscernibles' (PII) (if two objects share all their properties, then they are identical, they are the same object). In fact, quantum particles are characterized by a kind of behavior that that is not compatible with a notion of identity based on the properties instantiated by items, in particular on their spatiotemporal properties.

The book is organized in 9 chapters. Chapters 1-4 deepen the metaphysical issues about identity end individuality with respect to the history of contemporary physics, underlying how the status of particles has changed moving from classical to quantum physics. In chapters 5-9 a set theory and a logical system are defined in order to provide an appropriate formal framework

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for 'non-individuals', that is, objects which individuation is not compatible with PII.

In the introduction (chapter 1) the authors delineate the main metaphysical options about identity. On one hand we have the traditional notion of individuality, based on PII, that states that individuality is conferred by the set of the qualitative properties that an entity instantiates: two objects that are indistinguishable (that is, that share the same properties) cannot be two different objects; following this approach there is a perfect correspondence between the notions of *individuality* and *distinguishability*. On the other hand there is a transcendental notion of individuality, where every individual is defined by 'something else', transcending ordinary properties (this approach has taken many form in the history of metaphysics, and the authors do not commit to any particular one); in this case the fact that two entities are two distinct individuals does not imply that they are distinguishable with respect to the properties they instantiate.

While classical physics is compatible with an approach based on PII (chapter 2), by referring ultimately to the spatiotemporal properties of the particles, quantum physics cannot share such an approach (chapter 3), for more than one reason. First, quantum entities cannot be distinguished on the basis of their properties, even the spatiotemporal ones, since the failure of the 'assumption of impenetrability' in quantum physics prevents any reference to the spatiotemporal properties for determining the individuality of particles. Moreover, when quantum particles become entangled with one another, their collective state is not reducible to their separate, individual states, and so the relations between particles acquire a kind of ontological value, respectful of the holistic aspect of quantum reality. Finally, there is a difference in the statistical approach: on one hand classical statistical mechanics are based on a model that treats every particle as a particular distinct individual, and so all the aggregative configurations which are structurally equivalent but differ for a permutation of the particles are considered distinct states of a system; on the other hand in quantum statistics some types of particles cannot be 'labeled', that is, they cannot be treated as distinct individuals, and so the different states are distinguished only with respect to their configurations, regardless of the possibility of permuting the particles.

Hence, the quantum particles violate PII, and this takes to the main question about their individuality (chapter 4): can they be seen as characterized by a kind of transcendental individuality, or are to be considered as *non-*

individuals? The authors conclude that the results of quantum physics are not determinant for a choice between these two options, and they can be both embraced, even if the 'non-individual' approach is preferable since it meshes better with the framework of quantum field theory. The main point is that the metaphysical issues are not univocally determined by the physics, leaving the space for different options. Notwithstanding, it is possible to develop a logical formalization that results appropriate as a model of quantum objects, independently of the particular metaphysical option chosen.

The rest of the book is devoted to the formulation of such a formal theory for non-individuals.

Formally, to be an individual means first of all to satisfy the law of identity (for every x, x=x, that is, every object is identical to itself). Hence, the main idea is to define a semantics and a logic such that the law of identity is not satisfied, that is, the formula 'For every x (x=x)' is not valid anymore. Since such a law is ineradicable from classical set theory, French and Krause point to the definition of an alternative theory that avoids the validity of the law of identity. They take as a basis Dalla Chiara and Toraldo di Francia's *quaset theory* (chapter 5), and Da Costa's *System S* (chapter 8).

Semantically, they present the *Quasi-set theory* (chapter 7). Quasi-set theory is a two-sorted set theory, with two types of elements: the M-atoms are classical set-theoretic elements, while the m-atoms are 'quasi-objects', non-individuals. If we restrict our attention to the former type of atoms, we remain in the field of the classical set-theory, while if we consider also the m-atoms, we obtain a system that distinguishes between a relation of indistinguishability '≡' and a relation of identity '='; in the theory we have that, while a 'law of indistinguishability is always satisfied (for every element x, x≡x), the law of identity is not valid anymore (it is not true anymore that for every x, x=x).

Then, starting from Da Costa's *System S*, French and Krause define their *Schrödinger Logics* (chapter 8), a class of non-reflexive (that is, not satisfying the law of identity) logical systems that can be characterized by a semantics based on quasi-set theory.

The last chapter is dedicated to recap and take stock of the situation.

The work presented by French and Krause is impressive. The book is not an easy reading: there is a continuous reference to the main results in quantum physics, and a good background in the modern history of physics is also required; moreover a good familiarity with formal logic is necessary to cope with the last chapters of the book. Indeed, people with an appropriate

background for appreciating this book from all the angles are presumably quite a few, and I am surely not one of those. However, also a partial estimation of the value of the various investigated issues can be extremely fruitful, and the authors are always mindful in presenting the general problems and the main results of their endeavour in an accessible way. In the end, for the multiplicity and the richness of the topics involved, this book is not only an important contribution to a particular issue, that is, the notion of identity and its relation with contemporary physics, but it reveals itself as a significant text for the philosophy of physics in general.