Individuality, Distinguishability, and (Non-)Entanglement

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Abstracts

Tomasz Bigaj, ***On the Physical and Metaphysical Roots of the Symmetrization Postulate***
In my talk I would like to get back to basics and reexamine the various reasons that are supplied in support of the symmetrization postulate (SP) in the quantum theory of many particles of the same type. I will focus my attention on the loose and informal arguments offered for SP in many textbooks. It is often said that the necessity of symmetrizing states of many 'identical' particles comes from the fact that labels used in the tensor formalism are 'unphysical', and that non-symmetric states should be eliminated because they permit tests that are sensitive to the permutation of labels. This argument is baffling for a variety of reasons. As particles of the same type can clearly be prepared in distinct physical states (e.g. different positions), labels can be attached to particles through these initial states, and therefore can be subject to tests that are realizable in practice. A slightly less controversial argument proceeds from the assumption that permuted non-symmetric states are physically indistinguishable which leads to the problem known as exchange degeneracy. The problem comes to the surface when we apply the superposition principle, since various superpositions of permuted states are clearly distinguishable by means of physically realizable tests. A thorough analysis of this argument requires some heavy metaphysical assumptions regarding the interpretation of permuted states. I will first introduce a distinction between 'passive' and 'active' interpretations of state permuting, where passive permutations amount to a mere relabeling of a state with no change in the physical system. With regard to the active interpretation of permutations we can either follow Kripke and his 'individualistic' characterization of the post-permutation state (where labels are treated as rigid designators), or use Lewis-style essentialism that dispenses with non-qualitative characteristics altogether. Subsequently I'll try to use these metaphysical positions to clarify the meaning of symmetric and antisymmetric states and analyze the consequences of SP concerning the problem of quantum (in-)discernibility.

Jeremy Butterfield, ***States, Quantities and Permutation Symmetries*** **(joint work with Adam Caulton)**
I will first survey the role of entanglement in the metaphysics of quantum theory, especially in relation to the identity and individuation of quantum particles. Then I defend for quantum theory a position I call 'structuralism'. Roughly speaking, a structuralist holds that an object can only be distinguished from other objects by its qualitative properties and the qualitative relations it holds to other objects. This means that a permutation of indistinguishable objects that preserves these qualitative properties and relations does not yield a different state of affairs. I emphasize: (i) the general relations between states, physical quantities and symmetries (including symmetries other than permutation symmetries; (ii) the analogies and disanalogies, both technical and interpretative, with classical mechanics.

Adam Caulton, ***How to Russell a Fermi-Dirac***

Common practice in many-particle quantum mechanics consists of a variety of interconnected calculational procedures and interpretative assumptions concerning the constituent particles and their states. Chief among them is the assumption (coined 'factorism' by Jeremy Butterfield) that factor Hilbert space labels denote or correspond to the constituent particles. This assumption feeds into the motivation for extracting the states of constituent particles through a partial trace procedure. In the context of permutation-invariant quantum mechanics, in which expectation values are invariant under arbitrary permutation of Hilbert space labels, the ineluctable conclusion follows that all particles of the same species occupy the same (typically statistically mixed) state, and so are, in the terminology of Quine, absolutely indiscernible.

However, factorism may coherently be denied. A promising alternative seeks to individuate particles, not according to factor Hilbert space labels, but rather according to their state-dependent properties. I aim to flesh out this alternative, which has close affinities with Russell's celebrated account of denoting phrases. On this alternative, particles are often absolutely discernible. Moreover, this approaches meshes well with an alternative notion of entanglement, propounded elsewhere by Ghirardi, Marinatto and Weber. I justify this notion of entanglement further by appeal to an analogue of Gisin's Theorem, which applies to bipartite fermionic systems.

As I hope also to show, a further consequence of this promising alternative is that particles are "emergent objects" – a fact we know anyway from quantum field theory, but which is intimated already in the domain of conserved total particle number.

Cord Friebe, ***Leibniz, Kant, and the Quantum Individuals***

The aim of my talk is to defend a Kantian way of referencing in the quantum domain, i. e. solving the labelling problem with irreducible demonstratives. According to the straightforward reading of the mathematical formalism of standard quantum mechanics, content-free numbers directly refer to basic particulars. They, then, may be regarded either as weakly discernible by relations such as 'having opposite spin' or as utterly indistinguishable. Against this view(s), and based on the distinction between purely permutation invariant states and physically entangled ones, it has been argued that, instead of numbers, descriptive proper names refer to the physical particles which rather are absolutely distinguishable satisfying Leibniz's principle in a strong(er) sense.

Kant's way of referencing, by contrast, goes without any labels or names but – thanks to 'intuition' – with irreducible demonstratives, i. e. demonstratives that are independent from coordinates. This not only works better in the domain of quantum mechanics but, also, it is broader in scope and may work even in quantum field theory with vague numbers of particles.

James Ladyman, ***Are Quantum Particles Individuals, Objects and/or Structures?***

This paper argues that quantum particles are objects in the logical sense of being values of variables and referents of singular terms, but that they are not individuals in various senses considered. It is argued that since there is little agreement about what the right sense of individual is the matter is somewhat moot anyway. It is argued that weak discernibility is not distinguishability. It is argued that since weak discernibility plus names implies absolute discernibility, and since there can be absolute but purely relational discernibility, there is no metaphysical significance to the difference between weak and absolute discernibility but rather a epistemic/semantic one. It is argued that an important issue for structuralism is how haecceitism relates to names, and that this also relates to broader issues of scientific representation.

Andrea Lubberdink, ***Particles and the World***

Regarding the ontology of quantum objects there are two main views. In both, Leibniz's Principle of the Identity of Indiscernibles is violated or saved in only a weak sense. I this presentation I will argue that the world gives us no choice but to save PII in a strong sense.

I will first elaborate on identical particles and permutation invariance on the classical level, where PII undisputedly holds. Also, the definition of classical objects is obvious and unquestioned.

But what is a quantum object? It is not a tiny, tiny classical object, since (early) quantum mechanics teaches us about wave-particle duality and the uncertainty principle. So the question arises if it does make sense to define particles in quantum mechanics at all?

In my opinion there is one (and only one!) significant reason for defining particles in quantum mechanics. It is given by the observable world. Indeed, the very essence of quantum mechanics is that it is a physical theory, connecting a mathematical structure to what we observe. And to observe, we need objects, distinguishable objects. So, any definition of particles in quantum mechanics should be able to refer directly to observable objects, be it in an approximate way.

F. A. Muller, ***The Rise of Relationals***

I begin by criticising an elaboration of an argument to the effect that, when Leibniz's Principle of the Identity of Indiscernibles (PIdIn) faces counter-examples, invoking relations to save PIdIn fails. I argue that insufficient attention has been paid to a particular dis- tinction. I proceed by demonstrating that in most putative counter-examples to PIdIn (due to Immanuel Kant, Max Black, Alfred Julius Ayer, Peter Frederick Strawson, Hermann Weyl, Christian Wüthrich), the so-called Discerning Defence trumps the Summing Defence of PIdIn. The general kind of objects that do the discerning in all cases form a category that has received little if any attention in metaphysics. This category of objects lies between indiscernibles and individuals and is called relationals – objects that can be discerned by means of relations only and not by properties. Remarkably, relationals turn out to populate the universe. This fits with a weak variety of structuralism, aka ontic structure realism.

Simon Saunders, ***Three Questions about Permutation Symmetry***

I address three questions: (i) why weak discernibles, (ii) whether descriptions using only bound variables (and no proper names) are already permutation invariant in the relevant sense, and (iii) is there diffusion of gases in the Gibbs paradox.

Lev Vaidman, ***Individuality, Distinguishability, and Non-Entanglement of a Person in the Many-Worlds Interpretation***

I will discuss the ontology of the universal quantum wave function and the ontology of the world wave functions in which macroscopic objects are not entangled and "live" in three dimensions. I will argue that the individuality of persons has to rely on their own distinguishability and cannot rely on distinguishability of other objects in their worlds as was recently done in Sebens and Carroll proof of Born rule.

Tina Wachter, ***Back to the Roots: Leibniz's Principle in Quantum Mechanics***

There are various philosophical positions concerning quantum particle (non-)identity and the question whether the Leibnizian principle of the identity of indiscernibles (PII) is violated in quantum mechanics or not.

One of these positions is Ian Hacking's (1975) claim that any possible world can be described in such a way that the PII is preserved. I will discuss his position critically by showing that, while this approach is applicable to classical statistical mechanics and historical examples like Kant's two drops of water or Max Black's two iron spheres, it is insufficient for quantum statistical mechanics with permutation invariant particles. For this I use an argument by French and Redhead (1988) against Hacking which shows why his positions fails for quantum particles.