Studies in History and Philosophy of Modern Physics 50 (2015) 43–53

Contents lists available at ScienceDirect

Studies in History and Philosophy of Modern Physics

journal homepage: www.elsevier.com/locate/shpsb

Dissecting weak discernibility of quanta

Tomasz Bigaj [a,b]

[a] University of Warsaw, Institute of Philosophy, Warsaw, Poland
[b] Department of Philosophy, University of California, San Diego, La Jolla, CA, USA

ARTICLE INFO

Article history:
Received 8 October 2014
Received in revised form
6 February 2015
Accepted 18 February 2015
Available online 17 March 2015

Keywords:
Weak discernibility
Identity
Individuality
Elementary particles

ABSTRACT

In this paper I critically examine latest attempts to formalize quantum-mechanical relations that are supposed to weakly discern elementary particles. I argue that all of them make illegitimate and unavoidable reference to numerical identity, and therefore cannot be used as a means to ground (or derive) quantitative facts of identity/distinctness in the qualitative characteristics of quantum systems. I compare my criticism of weak discernibility with the general circularity objection known from the literature, and I show that my argument is more specific, as it is based on a particular criterion which differentiates between legitimate and illegitimate uses of identity. In the end I suggest that we should reevaluate the role of permutation invariance in expressing the facts of qualitative differences between particles. Taking into account the inevitable symmetrization requirement applied to operators in tensor product spaces, it may be claimed that particles of the same type can be absolutely discerned in some accessible states.

When citing this paper, please use the full journal title *Studies in History and Philosophy of Modern Physics*

1. The weak discernibility program: an overview

It has been more than 10 years since the emergence of the idea to exploit the logical concept of weak discernibility in discussions on the ontological status of quantum particles. During these years the original suggestion has grown into a full-blown metaphysical program aiming at deriving useful lessons regarding the identity and individuality of fundamental entities from our best physical theories, and making connections with other far-reaching metaphysical programs, such as ontic structuralism. In this critical survey I would like to focus on some technical aspects of weak discernibility in the context of non-relativistic quantum theory. One of the main conclusions of my analysis will be that the weak discernibility (WD) program applied to quanta is actually incapable of reaching all of its ambitious goals. The weak discernibility claims advanced with respect to quantum particles of the same type (bosons and fermions) are toothless as a tool for establishing interesting metaphysical conclusions regarding their status as full-fledged objects, and regarding the validity of non-trivial metaphysical principles, such as the Principle of the Identity of Indiscernibles.

Before we plunge into a detailed exegesis of the technical aspects of the WD program, it may be appropriate to remind the reader of the historical development of this approach. For the purpose of bookkeeping I suggest distinguishing four stages of development of the WD program. The first stage, which may be called *Promising beginnings*, is associated with the name of Simon Saunders. At the time when the dominating view among physicists and philosophers had been that the PII is violated in quantum mechanics, and that quanta most probably lack any individuality due to their indiscernibility, Saunders had the audacity to go against the flow and argue that there is a largely forgotten sense of discernibility which may be applicable even to elementary particles (Saunders, 2003, 2006). Saunders rediscovered the Hilbert–Bernays method of defining identity using qualitative predicates only, and argued that Quine's weak discriminability on which this method is implicitly based is attainable for fermions of the same type. Fermions in antisymmetric states can be discerned by the relation of having opposite spins, and therefore are legitimate objects. On the other hand, bosons in symmetric product states remain utterly indiscernible, and as such can be interpreted as *aggregates* only.

The second stage of the program, which I refer to as *Sharpening the arguments* is marked by the arrival of Fred A. Muller on the scene. Many critics of Saunders' early attempts to weakly discern

E-mail addresses: t.f.bigaj@uw.edu.pl, tfbigaj@gmail.com

http://dx.doi.org/10.1016/j.shpsb.2015.02.003
1355-2198/

fermions pointed out that it is strictly speaking incorrect to claim that the relation of having opposite spins can connect two fermions in the singlet state, since individual particles do not possess any precise values of spin. In order to repel similar objections, Muller and Saunders (2008) joined forces and made an effort to develop a technically rigorous and conceptually sound method of weakly discerning fermions in all admissible states using categorical (i.e. non-probabilistic) properties only. In this approach bosons remained at a slight disadvantage, since their discernibility was achieved only with the help of probabilistic relations. However, in a follow-up paper Muller and Seevinck (2009) strengthened even this claim, showing how to discern fermions, bosons and any other particles in terms of eigenvalues of particular quantities, and hence categorically.

After this major victory, the program took a sharp *Metaphysical turn*, and therefore entered its third stage, punctuated by two papers (Muller, 2011, 2015). In them, the technical results achieved in the previous phase are elevated to the status of sweeping metaphysical claims about the ultimate nature of physical reality and its governing principles. Muller abandons the traditional dichotomy between individuals and non-individuals, introducing a third category of entities: relationals. Fundamental objects in physical theories are determined by the relations they participate in, and this gives support to the broad structuralist stance. On the other hand, far from being committed to the trash heap of history by the development of quantum mechanics, PII actually receives a boost and comes out victorious as one of the most scientifically justified metaphysical principles.

I suggest that the fourth stage in the development of the WD program be identified with *Friendly criticism* done by authors who do not question the main goal and general results of the program but notice some gaps in the arguments by Muller, Saunders and Seevinck that need to be filled out.[1] Two recent papers by Adam Caulton (2013) and Nick Huggett and Josh Norton (2014) are representative of this stage.[2] Both papers aim at improving rather than rejecting the WD program by selecting new discerning relations that are better suited for the task. Later in the text we will discuss the details of these critiques, and we will see that some of the objections raised in them reveal much more serious problems with the WD program which cannot be easily remedied by simply choosing a new discerning quantity.

The ostensible goal of the WD program is to rehabilitate the Principle of the Identity of the Indiscernibles, which has fallen on hard times in quantum mechanics.[3] This in itself is a worthy undertaking. However, one can ask why we should be so keen to save the venerable Leibnizian principle, if not out of the respect for one of the greatest minds in philosophy and science. The PII tells us, in rough outline, that all numerically distinct objects have to differ qualitatively from one another (this is what we usually mean by "discernibility"). Muller (2015) formulates three reasons why we should care about such a claim. The first reason given by Muller is not so much a motivation why we should want PII to be true, as an explanation of why we should not ignore it if it is indeed true ("because it teaches us an ontological lesson" is the submitted answer). The second reason is associated with Muller's preferred metaphysics of relationals, and as such does not extend to all forms of PII, only the ones based on relational discernibility. The third adduced reason is that PII supplies us with clear identity criteria. This observation is echoed by Saunders in (2003, pp. 289–291), where he stresses that the truth of the PII enables us to reduce numerical identity to qualitative facts, and therefore eliminates the need for identity as a primitive predicate. Saunders insists that while in general there is nothing wrong with identity taken as primitive, in the context of physics it is better to see it as derivative. He points out that physical objects are known to us through descriptions as objects of predications, and not as some formal constructs. Thus descriptions in terms of pure physical properties should enable us to recognize objects of physical theories as entities numerically distinct from one another.

I hope it would not be a gross distortion of the WD program to sum up the above ideas as follows. We need the validity of (some form of) PII, because we want to be able to ground facts regarding numerical distinctness (numerical identity) of objects in some qualitative facts pertaining to their arrangements.[4] And the possibility of achieving such grounding (or reduction, to use another fashionable term) in a principled manner can ensure some important metaphysical conclusions regarding the status of the entities in question (that they are objects, or individuals, or at least *relationals*). Moreover, specific methods of achieving the required grounding can give support to independent metaphysical claims, such as the claim of the ontological primacy of relations (structures) over objects, commonly known as ontic structuralism.[5]

The notion of discernibility figuring in the formulation of PII admits various interpretations.[6] The standard version of PII employs discernibility by properties, typically referred to as absolute. The two other grades of discernibility are: relative and weak discernibility. Two objects are relatively discernible if there is a relation that connects them in one direction but not the other.[7] Weakly discerning relations, on the other hand, are such that they hold between two distinct objects, but do not hold between an object and itself. Note that from this characterization it trivially follows that if objects a and b are weakly discerned by relation R, they must be distinct entities: $a \neq b$. This fact may be seen as the formal basis of the grounding claim: the non-qualitative fact that a and b are numerically distinct can be reduced to (or inferred from) the fact that they are connected by the qualitative relation R. However, we should keep in mind that the grounding is successful

---

[1] In my current exposition of the WD program I largely ignore the not-so-friendly criticism of weak discernibility advanced e.g. by Hawley (2006, 2009), French & Krause (2006), van Fraassen & Peschard (2008), Dieks & Versteegh (2008), and Ladyman & Bigaj (2010). However, some echoes of these critiques will reverberate later in the text, mostly in Section 5.

[2] It should be added here that Caulton no longer supports the WD program (private communication). See footnote 19 for reference to his latest unpublished work on the problem of discernibility of quantum particles.

[3] Some of the key authors responsible for exposing the apparent plight of PII in QM are Margenau (1944), French & Redhead (1988), Giuntini & Mittelstaedt (1989), Redhead & Teller (1992), and Butterfield (1993).

[4] In my Bigaj (2015) I point out that there is yet another possible use that PII can be put to: it can namely help distinguish one object from the rest of the universe in a way which makes it possible to uniquely refer to it. I argue that weak discernibility is incapable of reaching this goal; however, there are grades of discernibility weaker than absolute but stronger than weak discernibility that may achieve such identification of objects.

[5] I admit that some pronouncements of the proponents of the WD program can be interpreted as claims of a more methodological than metaphysical character. That is, the existence of weakly discerning relations may be seen as ensuring that facts regarding numerical identity and distinctness can be derived from empirical, qualitative statements, without presupposing that the latter facts ground the former. However, my subsequent criticism of the WD program can easily be showed to apply to its methodological interpretation as well. If, as I claim it to be the case, the relations used to weakly discern quantum particles make inescapable reference to numerical identity, the derivation of the non-qualitative facts of identity from qualitative facts involving weakly discerning relations is circular. Thus, in order to argue that particles a and b are numerically distinct, we have to presuppose the very fact we want to establish.

[6] For recent logical analyses of the variety of grades of discernibility see Ketland (2011), Caulton & Butterfield (2012), Ladyman, Linnebo, & Pettigrew (2012) and Bigaj (2014).

[7] Huggett & Norton in (2014, p. 40) mistakenly define relative discernibility of objects a and b by the formula $\exists \mathscr{R}, c\ \mathscr{R}(a, c) \wedge \mathscr{R}(b, c)$. This formula can be actually proven to be equivalent to weak discernibility (under the assumption that variable $\mathscr{R}$ ranges over all two-place formulas definable in given language). I am grateful to Chris Wüthrich for bringing that error to my attention and for a subsequent discussion.