Entities without intrinsic physical identity

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Abstract

This paper critically discusses recent objections that have been raised against the contextual understanding of fundamental physical objects advocated by non-eliminative ontic structural realism. One of these recent objections claims that such a purely relational understanding of objects cannot account for there being a determinate number of them. A more general objection concerns a well-known circularity threat: relations presuppose the objects they relate and so cannot account for them. A similar circularity objection has also been raised within the framework of the weak discernibility claims made in the last few years about quantum particles. We argue that these objections rely either on mere metaphysical prejudice or on confusing the logico-mathematical formalism within which a physical theory is formulated with the physical theory itself. Furthermore, we defend the motivations for taking numerical diversity as a primitive fact in this context.

1 Introduction: OSR and contextual identity

Ontic structural realism (OSR) is a recently much debated conception in the metaphysics of contemporary fundamental physics. In this context, it aims to provide an interpretative and ontological framework that accounts for the crucial features of fundamental physics. The ontological thesis of OSR can be broadly expressed in the following way: what there is in the world at the fundamental level (or in the cases where OSR is relevant) are physical structures, in the sense of networks of concrete physical relations among concrete physical objects (relata). Of course much hinges on the exact relationship between the objects (relata) and the relations in the structures.

The original version of OSR as developed by French and Ladyman (2003) suggests a purely relational, 'object-free' understanding of structures. Such alleged elimination of objects in fundamental ontology has provoked the major objection against this radical (eliminativist) version of OSR, namely that in repudiating objects, it is hardly intelligible as a metaphysical conception of the concrete physical world (see e.g. Chakravartty 2003).[1] In the face of this objection, efforts have been deployed in order to articulate some relational (thin) notion of objects (relata) in the structures to which OSR is committed. In this context, the relational nature of the objects (relata) is characterized in terms of ontological primacy and ontological dependence, giving rise to the two non-eliminativist variants of OSR (see the recent discussion and the references in French 2010, which still defends the radical, eliminativist version): either no ontological priority between relations and objects standing in relations (symmetric ontological dependence) or ontological primacy of relations over objects standing in relations (asymmetric ontological dependence of objects on relations, the objects being constituted by the relations in which they stand). We have argued

[1] Bain (2013) recently suggests that category theory provides a formal framework for this radical version of OSR; see Lam and Wüthrich (2014) for a critical perspective.

elsewhere that these characterizations might not be entirely satisfactory (Esfeld and Lam 2011): the distinction between objects and relations might be best regarded as purely conceptual rather than ontological, as usually assumed, so that relations (structures) can be understood as the ways (modes) in which objects exist, without being considered as ontologically distinct from objects.[2]

Beyond these (important) ontological subtleties, the crucial point for the OSR thesis is that fundamental physical objects (in the cases where OSR is relevant) do not exist apart from the physical structures they are part of and in particular do not possess any intrinsic physical identity, that is, any (qualitative) identity that is independent of concrete relations the physical objects in question enter into. In broad terms, 'physical identity' is the qualitative identity that can be ascribed to physical objects on the basis of the physical description provided by the relevant physical theory. It has to be clearly distinguished from the purely formal (logical, set-theoretic) notion of identity, which the just mentioned physical descriptions make use of. This distinction between the physical and formal notions of identity is central to the aim of this paper (see below).

In positive terms, the very existence of the OSR objects is relational (structural, contextual—we use these words interchangeably, as capturing the same idea here), in the sense that their very existence depends on the relations in which they stand (the structures they are part of) and on there being other objects (see French 2010 for a discussion of the relevant notion of 'existential dependence' in this context; see also recently Wolff 2012 and McKenzie 2013).[3] This broad characterisation of OSR actually encompasses a family of distinct metaphysical theses about identity, individuality and discernibility. These various specific theses disagree about whether facts about identity and individuality can be reduced to qualitative facts only and whether objecthood implies qualitative discernibility (and if yes, what kind of discernibility). We will address some of these issues in more details below, the important point for now is that, to the extent that they involve a relational understanding of objects, these different metaphysical theses fall under the OSR umbrella (see Caulton and Butterfield 2012a, §5.3 for a recent discussion of the links between these various theses and structuralism).

It has been argued that the ontological thesis of OSR is vindicated by fundamental aspects of our current best physical theories about matter (quantum theory, including quantum field theory) and spacetime (general relativity):[4] indeed, the fundamental quantum features of permutation invariance and quantum entanglement (or, more generally, quantum non-locality), as well as the fundamental general relativistic features of gauge-theoretic diffeomorphism invariance and background independence have all been taken to suggest all the same conclusion, namely that the fundamental physical objects (in a broad sense) under consideration (elementary quantum systems, spacetime

[2]We can draw on Spinoza's metaphysics in order to make this idea more precise. Following Spinoza's *Ethics*, one can understand properties and relations as modes, that is, concrete, particular ways in which objects are. There is no ontological distinction between objects and their properties and relations in the sense of modes: the modes are the way in which the objects exist. Objects do not have any existence in distinction to their ways of existence, and their ways of existence do not have any existence in distinction to the objects. One can draw a conceptual distinction between objects and their ways of existence, but not an ontological one, applying to reality.

[3]This 'existential dependence' of the objects on the relations in which they stand (or more precisely on there being other objects) is nicely encoded in the understanding of relations in terms of ways (modes) in which objects exist. Within this framework, objects explicitly belong to the fundamental ontology (in contrast to eliminativist, radical OSR), and are therefore not reduced to mere 'bundles of relations' (a conception that might face the 'relations without relata' objection): if relations are the ways (modes) in which objects exist, there is a clear and meaningful sense in which there are fundamental physical objects in the world—namely, there are objects whose existence depends on there being other objects (and in this sense, this conception clearly constitutes a non-eliminativist version of OSR, see Esfeld and Lam 2011), thus avoiding the 'relations without relata' objection.

[4]See e.g. French and Ladyman (2003), Lyre (2004), Rickles (2006), Stachel (2006), Ladyman et al. (2007, ch. 3), Esfeld and Lam (2008), Kantorovich (2009), Muller (2011), Caulton and Butterfield (2012b), French (2012), Lam and Esfeld (2012), Lam (2013).

points or regions) do not have any existence—and in particular not any identity—independently of the physical structure they are part of (independently of the physical relations they enter into). In other terms, according to the OSR proponent, fundamental physics suggests that there are physical structures at the fundamental level that do not require underlying objects possessing an intrinsic identity. From the OSR perspective, this general ontological claim remains relevant even if one considers that it does not provide a complete ontology yet, in particular of the quantum domain, as long as it does not specify precisely how the structures to which fundamental physics is committed are concretely implemented (that is, as long as the quantum measurement problem is not addressed; however, against what Esfeld 2013 suggests, the OSR proponent can argue that the fact that OSR provides a general ontological framework which remains genuine and can be further specified within the different realist quantum interpretations constitutes a positive and convincing feature of this conception).

As empirically adequate as it might be, the basis for the ontological framework of (non-eliminativist) OSR seems however threatened by a general argument that looms in the literature, a version of which has been recently put forward by Jantzen (2011), where it is argued that "no version of OSR which both retains objects and understand 'structure' in terms of relations can be successful." (433) The central claim of Jantzen (2011) is that (non-eliminativist) OSR cannot account for and even cannot coherently accept the fact that there is a determinate number of objects (relata) in the physical structures to which OSR is committed at the fundamental level. This paper aims to critically discuss this claim and its underlying argument, as well as the broader circularity objection against any relational (structural, contextual) understanding of objects. Furthermore, the aim is to clarify the ontological status of numerical diversity (plurality) in the physical structures described by fundamental physics.

The crucial point, which seems to be overlooked in Jantzen's argument as well as in the general circularity objection, is the fundamental distinction between the logico-mathematical and the physical aspects of the OSR structures. The confusions around this point are recurrent in the debates on OSR, so that it is worth highlighting the issues in some details. To be clear: our aim in this paper is not to evaluate the physical arguments in favour of OSR or to discuss to what extent it constitutes an adequate ontology of the physical world as described by fundamental physics. Independently of one's stance on OSR as an interpretative framework for fundamental physics, the issues about the coherence of the relational understanding of objects and about the status of fundamental numerical diversity are relevant to the debates in the metaphysics of objects in general.

2 The objection from cardinality

The central argument in Jantzen (2011) against (non-eliminativist) OSR mainly relies on two considerations, one metaphysical and one logical:

(i) The fundamental objects within (non-eliminativist) OSR lack any primitive identity; more specifically, they lack self-identity.

(ii) The dependence in the standard set-theoretic framework of the notion of cardinality on the notion of identity.

Within the framework of Jantzen's argument, (non-eliminativist) OSR is mainly characterized in terms of the ontological priority of structure over objects, which are "supervenient placeholders in that structure" (2011, 434). It is then argued that claim (i) encodes the ontological priority of structure within the framework of this OSR conception of objects: the underlying reasoning is

that since there is nothing to objects in this context beyond the ontologically prior structure, the objects cannot possess the non-qualitative and non-structural property (or relation) of self-identity. More specifically, Jantzen crucially understands (i) in terms of lack of formal identity relations in the logical or set-theoretical sense.

Claim (ii) is grounded on logical facts; the standard set-theoretic notion of cardinality relies on the notion of bijection or, more generally, on the notion of function, which in turn presupposes some notion of self-identity for the set elements. Indeed, the underlying intuition links the notion of cardinality to the notion of countability (in the finite cases), and this latter to the numerical distinctness of the considered set elements, which is ultimately based on their (primitive) self-identity (a set element is numerically distinct—and can be counted—in virtue of being identical with itself but not with the other set elements).[5]

Taken together, the claims (i) and (ii) seem to imply that (non-eliminativist) OSR is not compatible with there being a determinate number of objects (relata) in the fundamental structures that OSR is realist about. Indeed, since the objects within (non-eliminativist) OSR lack primitive identity relations (such as the reflexive relation of being identical with itself), there is no numerical distinctness among them on the basis of which they could be counted, so that there is no definite cardinality. This consequence constitutes Jantzen's objection against (non-eliminativist) OSR: "If one's ontology admits objects, it ought to admit determinate numbers of them." (2011, 439)

3 The broad objection: circularity

Indeed Jantzen's objection constitutes an aspect of a broader objection against grounding (accounting for) identity and individuality facts in terms of relations only (in other terms, this broad objection targets the relational understanding of the identity and individuality of objects). This general objection relies on a well-known circularity threat: the very notions of relation and structure presuppose some numerical diversity (i.e. facts about how many relata there are, facts about the numerical identity and the numerical distinction (non-identity) of the relata), and so any attempt to ground this latter in terms of relations only is bound to be circular.

This circularity threat has been recently much discussed in connection with the notion of weak discernibility and the related weak version of Leibniz's Principle of the Identity of Indiscernibles (PII). This latter (or weak PII) allows symmetric irreflexive relations to ground identity and individuality facts of otherwise qualitatively indiscernible objects, such as similar fermions or similar bosons, which are said to be only weakly discernible on this purely relational basis (Muller and Saunders 2008, Muller and Seevinck 2009). The coherence and meaning of weak discernibility (and of weak PII) are subject to much debate: apart from the worry about genuine qualitative discernibility itself (see Ladyman and Bigaj 2010), one of the major concerns is indeed circularity. As French and Krause (2006, 170-171) put it, "the worry is that in order to appeal to such relations, one has already had to individuate the particles which are so related and the numerical diversity of the particles has been presupposed by the relation which hence cannot account for it." Weak discernibility alone cannot ground facts about identity and numerical diversity since it seems mandatory to presuppose some identity and numerical diversity for the objects in order to apply the weak discernibility criterion (see also Hawley 2009). Furthermore, from a formal point of view,

[5] Jantzen (2011) also considers alternative notions of cardinality, such as within the quasi-set theoretic approach, and argues that they too ultimately rely on identity facts. See Arenhart (2012) and Arenhart and Krause (2013) for a rebuttal of Jantzen's objection in the quasi-set theoretic context. For the purpose of this article, we can restrict ourselves to standard set-theory and the standard (von Neumann), intuitive notion of cardinality described above—suffice is to note that quasi-set theory may well provide a favourable environment for OSR (Krause 2005).

it seems that the very fact of considering a domain of elements over which physical variables range presupposes some numerical diversity in the first place.

More precisely, the circularity concern about weak discernibility and more generally about the relational understanding of identity and individuality finds its roots at two different (interrelated) levels—a logical, mathematical level and a metaphysical level. The first is constituted by the standard set-theoretic background within which all our scientific descriptions are formulated. For instance, the irreducible quantification over elements in standard first-order logic and more generally the irreducible reference to the elements of the sets used in the mathematical formulations of physical theories seem to vindicate the view according to which facts about numerical identity and diversity of the relata are prior to any (logical, set-theoretic) notion of relation. Indeed, the standard set-theoretic definition of the notion of (irreflexive) relation (and of the notion of structure) makes ineliminable reference to the numerical diversity of the set elements involved in the definition. For instance, the binary (irreflexive) relation on a set $S = \{a, b\}$ between the elements $a, b \in S$ is defined as the ordered pair (a, b), where the ordered pair (a, b) is defined to be the set $\{a, \{a, b\}\}$. This set-theoretic definition clearly makes irreducible reference to the numerical diversity of the elements of the set over which the relation is defined. Therefore, in this set-theoretic perspective, any attempt to ground the numerical diversity of a set of objects only in terms of the relations holding among them is bound to be circular. It can be further argued—as Jantzen (2011) does—that the notion of well-defined numerical diversity (well-defined, determinate cardinality) requires the notion of self-identity of the considered objects (see above section 2); any relational (contextual) understanding of the identity of these objects is then bound to be circular too.[6]

At the metaphysical level, worries about weak discernibility and about the relational understanding of identity find their roots in a long ('atomistic') tradition, which can be traced back to Aristotle at least and according to which objects (in particular fundamental physical ones) have to be something in themselves over and above the relations in which they stand, that is, objects have to possess some identity independently of there being other objects—some intrinsic identity. Within such metaphysical framework, any attempt to ground the identity of (fundamental physical) objects only in terms of the relations holding among them clearly is a non-starter.

4 Mathematical framework and physical theories

However, it must also be clear that the metaphysical framework according to which objects have to possess some intrinsic identity prior to entering into relations can be coherently rejected. That is precisely what OSR does, motivated by the evidences coming from fundamental physics. The fact that OSR and its relational (contextual) understanding of objects and their identity are not compatible with this 'atomistic' framework does not constitute any objection against OSR and the related notion of identity (that would be a mere prejudice). On the contrary, within the context of the naturalistic move in metaphysics, the metaphysical framework that can best accommodate our current fundamental scientific descriptions is to be preferred (and, again, the development of OSR has been precisely motivated by the novel features described by fundamental physics).

The logical side of the circularity threat to the relational (contextual) understanding of numerical diversity and identity as well as Jantzen (2011)'s cardinality objection against OSR discussed in section 2 both rest on a confusion between the broad logico-mathematical framework within which a physical theory is formulated (e.g. standard set theory) and the physical theory itself.

The OSR conception and its contextual identity thesis are about physical ontology (of some

[6] As already mentioned above (see footnote 5), the proponent of quasi-set theory argues that determinate cardinality does not necessarily presuppose self-identity (Arenhart 2012, Arenhart and Krause 2013).

physical domain where OSR is relevant), i.e. claims about what there is in the physical world (or in some relevant subsets of it). These latter rely on the physical descriptions provided by the relevant physical theories, which are of course formulated within the broad logico-mathematical framework just mentioned. But when aiming at ontological claims, the physically meaningful descriptions rather than the entire logico-mathematical framework within which they are formulated should be the centre of focus ('physically meaningful' is understood here in a very general way, referring to what is central to the corresponding physical theories and their account of the empirical data; in particular, this understanding is neutral with respect to the issue of the ontological relationship between 'mathematical' and 'physical' entities). Considerations based on the logico-mathematical framework alone are therefore inept at producing well-grounded ontological claims about the physical world as described by fundamental physics.

In particular, Jantzen (2011)'s argument crucially relies on (non-eliminativist) OSR being committed to rejecting (primitive) logical and set-theoretical (self-)identity relations in the context of the logico-mathematical characterisation of (non-eliminativist) OSR. Within the formal framework of standard set theory, the argument then exploits the fact that the very notion of cardinality (in the standard sense) depends on some (primitive) identity facts (see section 2).

Now, as discussed in the introduction, non-eliminativist OSR is a thesis about *physical* objects and structures: more specifically, according to non-eliminativist OSR, fundamental physical objects (in the cases where OSR is relevant) do not exist apart from the physical structures they are part of and do not possess any intrinsic *physical* identity, that is, any (qualitative) identity that is independent of concrete relations the physical objects in question enter into. In particular, these OSR objects do not possess intrinsic qualitative features (properties), which could ground some intrinsic qualitative identity.

The fundamental physical objects (relata), relations and structures OSR is committed to are described by the relevant fundamental physical theories, which are formulated within the broad framework of standard set theory (or using set-theoretical and logical tools). This formal framework (or tools) should however not be confused with the physical theories themselves. To the extent that talk about identity is meaningful (whether or not it is the case might depend on one's conception about identity and possibly on the qualitative discernibility that is available as well—more below), OSR is committed to physical objects having some relational (contextual) physical identity, as described by physical relational facts; the corresponding formal expressions make use of the relevant set-theoretic and logical notions (such as logical self-identity). But these latter alone have no physical meaning—it is acquired once interpreted within a physical theory. Within the context of a reductive understanding of identity (according to which identity facts can be reduced to qualitative facts), 'physical identity' is the qualitative identity that can be ascribed to physical objects on the basis of the physical (qualitative) properties and relations described by the relevant physical theories (e.g. in terms of physically interpreted predicates). This has to be contrasted with the purely formal (logical, set-theoretic)—physically uninterpreted—notion of identity, which the just mentioned physical descriptions make use of.

Therefore, the core OSR thesis of contextual physical identity and lack of intrinsic physical identity or, more generally, the OSR thesis of contextual existence (see the introduction) does not commit non-eliminativist OSR to rejecting primitive logical self-identity or strict set-theoretical identity relations within the logico-mathematical formulation of the relevant physical theories. At the level of the formal representation of the physical theories under consideration, the formal objects representing physical objects can (and do) stand in (primitive) logical and set-theoretical identity relations, and yet the physical objects they represent can (and, in the relevant cases, do) lack any intrinsic physical identity. In other terms, the thesis of contextual physical identity or lack of intrinsic physical identity at the level of the physical theories (at the ontological level described

by the fundamental physical theories) does not imply any lack of formal identity relations at the level of the formal representation of the physical theories.[7] As a consequence, since this implication constitutes one of its premises, Jantzen (2011)'s argument against non-eliminativist OSR and its contextual identity thesis does not go through.

To some important extent, the case of the circularity objection to the notion of relational identity and to the notion of weak discernibility is similar to the case of Jantzen (2011)'s objection against (non-eliminativist) OSR in that is also relies on some confusions around the distinction between the logico-mathematical framework within which physical theories are formulated and the physical theories themselves. It is however a bit less straightforward, and there are a few subtle (and controversial) aspects that need to be carefully considered.

On the one hand, it is clear that the formal (logical, set-theoretical) representation of an irreflexive physical relation does presuppose some formal numerical diversity. But the point of the proponents of weak discernibility (and of the proponents of non-eliminativist OSR—they need not be the same) is that this purely formal fact alone has no implication for the nature of the physical identity (and individuality) of the described physical elements—in particular, whether it is intrinsic or not. This latter issue has to be investigated within the relevant physical theory, whose description (e.g. in terms of physically interpreted predicates) can well motivate a relational understanding of the identity (and individuality) of the physical objects under consideration. In this perspective, claims about weak discernibility only are metaphysically informative in that they do physically motivate such a relational understanding (which was not presupposed in any way); in this sense, these claims are not circular (see Muller and Saunders 2008, §6 against the circularity objection to their weak discernibility results).

On the other hand, it seems that concrete, physical (irreflexive) relations do presuppose some physical numerical diversity of the physical objects involved. For there to be physical irreflexive relations, there must be a plurality of physical objects to be related (two in the case of binary irreflexive relations)—which is not to say that these relata must have some existence (identity) independently of the relations in which they stand. To some extent, the point is linked to the 'relations without relata' objection to radical, eliminativist OSR (see the introduction): indeed, the argument according to which concrete, physical (irreflexive) relations require concrete, physical relata that stand in relations seems to imply some (relevant) numerical diversity for these relata. Of course, the proponent of radical, eliminativist OSR will reject this implication (as well as the original argument) as metaphysically prejudiced (French 2010). We do not need to enter this debate here (apart from the comments made in the introduction); suffice is to note that if the 'relations without relata' argument is accepted, then it can be easily argued that claims about weak discernibility only can hardly account for the physical numerical diversity of the considered objects, on pain of circularity (a similar consideration can be made about physical numerical diversity within the framework of non-eliminativist OSR). But this fact does not render weak discernibility or non-eliminativist OSR circular altogether. Indeed, it has been recently suggested in this relational context that numerical diversity should be taken as a primitive fact—although this might look somewhat surprising at first sight. We examine this suggestion in the next section.

[7] We are not suggesting here that the broad standard mathematical (logical, set-theoretic) framework within which physical theories are usually formulated is not metaphysically loaded at all—it is to some extent, but mainly once physically interpreted. In this sense, we don't think for instance that standard set theory with identity is committed to an ontology of individuals that possess some primitive intrinsic thisness (represented by the formal primitive self-identity relation in this context). Therefore, as interesting as it might be on its own right, the motivation (especially from quantum physics) for quasi-set theory does not appear to us as strong as it is claimed to be. Of course, it might still be interesting to look for alternative formal frameworks, which could allow physical theories to develop in new directions.

5 Primitive numerical diversity and contextual objects

There is a double motivation for accepting numerical diversity as primitive within the framework of non-eliminativist OSR. First, it obviously dissolves the possible worries around the controversial issue of the status of numerical diversity in this purely relational context. Second, it enables non-eliminativist OSR to explicitly free itself from any commitment to PII—while remaining compatible with it, in particular in its weak version (see Ainsworth 2011 for a discussion of the links between OSR and PII)—and to allow for contextual but completely indiscernible objects, in the sense of not even weakly discernible objects.[8]

At first sight, it might seem surprising to take as primitive facts about numerical diversity (i.e. facts about numerical identity and distinctness) in the context of the relational understanding of objects: indeed, primitive numerical diversity runs against the reductive account of identity (and individuality) in terms of qualitative facts that is usually associated with OSR. Moreover, primitive numerical diversity is more often associated with the conception according to which every object possesses the unique non-qualitative intrinsic property of being the object it is (some 'primitive thisness' or 'haecceity').

There is however a big difference between primitive numerical diversity in the haecceitistic context (primitive intrinsic diversity or haecceitistic diversity) and primitive numerical diversity in the OSR context (primitive contextual diversity). The former is a diversity of 'isolated' individuals—individuals in the strong sense of being absolutely discernible (in a non-qualitative way) in virtue of their haecceitistic properties—possessing some (non-qualitative) intrinsic identity, whereas the latter is a diversity of what can be called 'contextual objects', which have no existence (and no identity, no individuality) independently of the (actual) structures they are part of. This last point shows in particular that primitive contextual diversity does not imply haecceitistic differences (it is meaningless to consider contextual objects independently of the actual qualitative relations they enter into, independently of the actual qualitative structures they are part of), whereas haecceitistic diversity does (Ladyman 2007), at least within the general understanding (but see below). Indeed primitive contextual diversity is more naturally associated with the denial of such haecceitistic differences, which is in line with fundamental physical features such as general permutation invariance in quantum theory and general relativity (see the introduction and in particular the recent discussion in Caulton and Butterfield 2012b).

Although primitive contextual diversity is a coherent move for the proponent of the relational understanding of objects, the very motivation for the *contextual* aspect of primitive diversity—to be contrasted with the motivations for the primitive status of contextual diversity above—has been recently put into question by Dorato and Morganti (2013). There are two main steps in their argument. First, they argue that a diversity of primitive *intrinsic* identities (individualities) is as metaphysically acceptable (from a naturalistic standpoint) as primitive contextual diversity.[9] Once it is explicitly recognised that something must be accepted as primitive, the 'metaphysical cost' of primitive intrinsic identities is claimed to be no higher than the 'cost' of primitive contextual

[8] Completely indiscernible objects easily appear in the mathematical domain (see Leitgeb and Ladyman 2008, who on this basis argue for primitive numerical diversity within mathematical structuralism); whether there are such physical objects is an open (and controversial) question. In this context, primitive numerical diversity has been considered in Pooley (2006), Ladyman (2007), Esfeld and Lam (2008, 2011); see also the recent discussion in Caulton and Butterfield (2012a).

[9] "We have already argued that primitivists can agree wholeheartedly with reductionists that mysterious, real yet non-physical, entities should be avoided when providing an account of reality. [...] But then it follows that, *exactly in the same way as the relations of numerical difference emphasised by the contextualists*, primitive intrinsic identities need *not* be taken to constitute 'metaphysical additions' to the qualities of things, and *may* simply coincide with fundamental, ungrounded facts about the existence of certain entities" (Dorato and Morganti 2013, 602).

diversity, since they argue that primitive intrinsic identities do not necessarily entail haecceitistic differences either. So, primitive intrinsic identities too are compatible with the denial of haecceitistic differences that is suggested by fundamental physics.

This leads us to the second step of Dorato and Morganti (2013)'s argument: in the case of non-relativistic quantum mechanics, they argue that the mere fact that a well-defined number of particles is always presupposed should be ontologically understood as encoding a primitive fact about the diversity of individuals with (primitive) intrinsic identity. In particular, they discuss the recent results about the weak discernibility only of quantum particles and argue that these results presuppose a well-defined cardinality that should be ontologically read in terms of primitive individuals with intrinsic identity. According to Dorato and Morganti (2013), this primitive diversity of intrinsic identities that is encoded in the very formalism of non-relativistic quantum mechanics bypasses the attempts to ground identity and individuality facts using weak discernibility claims (which moreover face circularity worries): in their perspective, the primitivist move (about intrinsic identities) is more straightforward (it follows from the very formalism within which non-relativistic quantum mechanics is expressed), less controversial (it does not face any circularity worries) and less revisionary (it does not question the 'atomistic' tradition) than the weak discernibility claims.

It is interesting to note the analogy between Dorato and Morganti (2013)'s argument for primitive intrinsic identities and Jantzen (2011)'s objection against non-eliminativist OSR (see section 2): in both cases, the fact of there being a definite cardinality of fundamental physical objects—here quantum particles—is thought to constitute a difficulty for the relational (contextual) understanding of these objects. Whereas the latter argues that non-eliminativist OSR cannot account for such a definite cardinality, the former claim that the well-defined number of particles in non-relativistic quantum mechanics is best understood in terms of primitive intrinsic identities rather than in terms of 'contextual particles'. We have argued in section 4 that Jantzen (2011)'s objection relies on a confusion between the logico-mathematical formalism within which a physical theory is formulated and the physical theory itself. To some extent, Dorato and Morganti (2013)'s argument for primitive intrinsic identities falls prey to a similar confusion.

Indeed, Dorato and Morganti (2013) argue that non-relativistic quantum mechanics always presupposes a well-defined number of particles, and that this fact should be taken ontologically seriously. As we have just seen, this is a defensible move (especially once it is explicitly recognised that something must be accepted as primitive), at least within non-relativistic quantum mechanics.[10] However, they then crucially assume that such a (primitive) determinate numerical diversity entails a diversity of individuals with (primitive) intrinsic identity. We have argued in this paper that this entailment does not hold. Indeed, a well-defined number of physical objects does not entail anything about their (physical) identity being intrinsic or not. The situation is similar to our critique of Jantzen (2011)'s argument in section 4: a definite cardinality of physical objects does not entail that these objects possess an intrinsic physical identity merely in virtue of being represented by set elements that are self-identical.[11]

Moreover, Dorato and Morganti (2013) explicitly set themselves in the framework of the naturalistic approach to metaphysics. Part of their paper actually aims to show that such a naturalistic

[10] Dorato and Morganti (2013) restrict their 'primitivist' considerations to non-relativistic quantum mechanics, where the particle number is always well-defined. More generally, they advocate a form of 'pluralism' with respect to identity and individuality, possibly with different approaches at different levels.

[11] Arenhart and Krause (2013) have recently also highlighted the analogy between Dorato and Morganti (2013) and Jantzen (2011): both assume that a definite cardinality requires individuals with intrinsic identity. As mentioned above, using quasi-set-theoretical tools, Arenhart and Krause (2013) further aim to show that the very formal notion of self-identity is not required for a definite cardinality (see footnote 7 for a comment on this program in relation to this paper).

approach is compatible with taking numerical diversity as primitive. As we have seen above, the proponent of the relational understanding of fundamental physical objects can fully agree with them on this point. However, the primitive diversity of individuals with intrinsic identity they advocate in the case of non-relativistic quantum mechanics does not take into account the fundamental features of the theory itself (such as permutation invariance and quantum non-locality—see the introduction). Even if this diversity of primitive intrinsic identities allegedly does not entail haecceitistic differences, it seems that it is assumed rather independently of the physics after all: as we have just seen, it does not follow from the mere fact that non-relativistic quantum mechanics always presupposes a well-defined number of particles and it does not take into account the specific quantum features such as permutation invariance and quantum non-locality.[12] The result can hardly constitute a substantive form of naturalism. By contrast, primitive contextual diversity explicitly aims to encode the physical features of permutation invariance and quantum non-locality and is in good harmony with the related results about weak discernibility (as well as with the fact that non-relativistic quantum mechanics always deals with a well-defined number of particles).

6 Conclusion

In this paper we have defended the coherence of the relational (contextual) understanding of fundamental physical objects (e.g. within non-eliminativist OSR)—the coherence of fundamental physical contextual objects—against objections that have been recently discussed in the literature. We have argued that these objections rely either on mere metaphysical prejudice or on confusing the logico-mathematical formalism within which a physical theory is formulated with the physical theory itself.

Fundamental physical contextual objects possess an existence that is dependent on the physical structures they are part of; in particular, they do not possess any intrinsic physical identity and individuality. We have shown that this characterisation of physical contextual objects does not prevent them from being in determinate number and from being represented by self-identical set elements (against the cardinality objection of Jantzen 2011). Most importantly, we have argued that the core theses at the heart of the notion of contextual object (existential dependence on structure and lack of intrinsic physical identity) do not involve any circularity.

However, we have seen that legitimate circularity concerns may be raised in this framework if all identity facts, in particular facts about numerical diversity, are thought to be reducible to qualitative relational and structural aspects only. In this reductive perspective where identity facts are understood in terms of qualitative (in)discernibility, circularity worries have been lately much discussed in relation to recent claims about the weak discernibility only of fundamental physical objects. Whether a throughout reductive account of identity and individuality in terms of qualitative relations only is coherent remains a controversial issue and depends to some extent on one's metaphysical intuition. We have underlined that the relational understanding of objects (such as within non-eliminativist OSR) is not tied to the reductive account of identity and individuality and therefore it is not touched by the related controversies.

In particular, we have considered the recent proposal of taking numerical diversity as a primitive fact in the framework of the relational understanding of objects. We have argued that it is a perfectly valid strategy in this relational framework and, most importantly, that it does not make 'good old' primitivism about the intrinsic identity and individuality of fundamental physical

[12] Dorato and Morganti (2013, §6) claim that the suggested diversity of primitive intrinsic identities is compatible with the results about weak discernibility (since all particles are qualitatively identical); however, the former is assumed quite independently of the latter.

objects (in particular non-relativistic quantum particles) preferable (against Dorato and Morganti 2013): indeed, the primitive contextual diversity of quantum particles (for instance) aims to encode the relational aspects suggested by fundamental quantum features such as permutation invariance and quantum non-locality (entanglement), whereas primitive intrinsic identities can be postulated independently of these fundamental physical features (so that the former seems more in line with the naturalistic approach to metaphysics). More generally, we hope to have shown that the relational (contextual) understanding of fundamental physical objects (such as within non-eliminativist OSR) is a coherent metaphysical conception, so one should stop worrying about this structural metaphysics. Rather one should focus on further evaluating its interpretative merits—beyond the many encouraging signs—with respect to the arguments coming from fundamental physics.

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References

Ainsworth, P. M. (2011). Ontic structural realism and the principle of the identity of indiscernibles. *Erkenntnis*, 75:67–84.

Arenhart, J. R. B. (2012). Many entities, no identity. *Synthese*, 187:801–812.

Arenhart, J. R. B. and Krause, D. (2013). Why Non-individuality? A Discussion on Individuality, Identity, and Cardinality in the Quantum Context. *Erkenntnis*, doi:10.1007/s10670-013-9429-4.

Bain, J. (2013). Category-theoretic structure and radical ontic structural realism. *Synthese*, 190:1621–1635.

Caulton, A. and Butterfield, J. (2012a). On Kinds of Indiscernibility in Logic and Metaphysics. *British Journal for the Philosophy of Science*, 63:27–84.

Caulton, A. and Butterfield, J. (2012b). Symmetries and Paraparticles as a Motivation for Structuralism. *British Journal for the Philosophy of Science*, 63:233–285.

Chakravartty, A. (2003). The structuralist conception of objects. *Philosophy of Science*, 70:867–878.

Dorato, M. and Morganti, M. (2013). Grades of individuality. A pluralistic view of identity in quantum mechanics and in the sciences. *Philosophical Studies*, 163:591–610.

Esfeld, M. (2013). Ontic structural realism and the interpretation of quantum mechanics. *European Journal for the Philosophy of Science*, 3:19–32.

Esfeld, M. and Lam, V. (2008). Moderate structural realism about space-time. *Synthese*, 160:27–46.

Esfeld, M. and Lam, V. (2011). Ontic structural realism as a metaphysics of objects. In Bokulich, A. and Bokulich, P., editors, *Scientific structuralism*, pages 143–159. Springer, Dordrecht.

French, S. (2010). The interdependence of structure, objects and dependence. *Synthese*, 175:89–109.

French, S. (2012). Unitary inequivalence as a problem for structural realism. *Studies in History and Philosophy of Modern Physics*, 43:121–136.

French, S. and Krause, D. (2006). *Identity in Physics: A Historical, Philosophical, and Formal Analysis*. Clarendon Press, Oxford.

French, S. and Ladyman, J. (2003). Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure. *Synthese*, 136(1):31–56.

Hawley, K. (2009). Identity and Indiscernibility. *Mind*, 118:101–119.

Jantzen, B. (2011). No two entities without identity. *Synthese*, 181:433–450.

Kantorovich, A. (2009). Ontic Structuralism and the Symmetries of Particles Physics. *Journal for General Philosophy of Science*, 40:73–84.

Krause, D. (2005). Structures and Structural Realism. *Logic Journal of the IGPL*, 13:113–126.

Ladyman, J. (2007). On the Identity and Diversity of Objects in a Structure. *Proceedings of the Aristotelian Society Supplementary Volume*, 81(1):45–61.

Ladyman, J. and Bigaj, T. (2010). The Principle of the Identity of Indiscernibles and Quantum Mechanics. *Philosophy of Science*, 77:117–136.

Ladyman, J., Ross, D., Spurett, D., and Collier, J. (2007). *Every Thing Must Go: Metaphysics Naturalized*. Oxford University Press, Oxford.

Lam, V. (2013). The entanglement structure of quantum field systems. *International Studies in the Philosophy of Science*, 27:59–72.

Lam, V. and Esfeld, M. (2012). The Structural Metaphysics of Quantum Theory and General Relativity. *Journal for General Philosophy of Science*, 43:243–258.

Lam, V. and Wüthrich, C. (2014). No categorial support for radical ontic structural realism. *British Journal for the Philosophy of Science*, forthcoming.

Leitgeb, H. and Ladyman, J. (2008). Criteria of Identity and Structuralist Ontology. *Philosophia Mathematica*, 16:388–396.

Lyre, H. (2004). Holism and structuralism in U(1) gauge theory. *Studies in History and Philosophy of Modern Physics*, 35(4):643–670.

McKenzie, K. (2013). Priority and particle physics: Ontic structural realism as a fundamentality thesis. *British Journal for the Philosophy of Science*, doi:10.1093/bjps/axt017.

Muller, F. A. (2011). Withering away, weakly. *Synthese*, 180:223–233.

Muller, F. A. and Saunders, S. (2008). Discerning Fermions. *British Journal for the Philosophy of Science*, 59:499–548.

Muller, F. A. and Seevinck, M. (2009). Discerning Elementary Particles. *Philosophy of Science*, 76:179–200.

Pooley, O. (2006). Points, Particles and Structural Realism. In D. Rickles, S. French and Saatsi, J., editors, *The Structural Foundations of Quantum Gravity*, pages 83–120. Oxford University Press, Oxford.

Rickles, D. (2006). Time and Structure in Canonical Gravity. In D. Rickles, S. French and Saatsi, J., editors, *The Structural Foundations of Quantum Gravity*, pages 152–195. Oxford University Press, Oxford.

Stachel, J. (2006). Structure, Individuality, and Quantum Gravity. In D. Rickles, S. French and Saatsi, J., editors, *The Structural Foundations of Quantum Gravity*, pages 53–82. Oxford University Press, Oxford.

Wolff, J. (2012). Do Objects Depend on Structures? *British Journal for the Philosophy of Science*, 63:607–625.