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ELIMINATIVE ONTIC STRUCTURAL REALISM AND THE METAPHYSICAL UNDERDETERMINATION ARGUMENT: A CRITIQUE

Abstract. In this paper I address the problem of justifying Steven French's eliminative ontic structural realism by the metaphysical underdetermination argument. My main goal is to show that there are underlying strategies in the argument and that they are questionable. I provide arguments for this claim and conclude that while the metaphysical thesis of eliminative ontic structural realism is dismissible, French's views can be characterized without it – at a very high price, however.

Keywords: eliminative ontic structural realism; metaphysics; quantum mechanics

1. INTRODUCTION

Ontic structural realism (OSR) was introduced in the philosophy of science to remedy two problems of scientific realism:[1] that of theory change and that of metaphysical underdetermination (Ladyman, 1998; French, 2014). In this paper I shall concentrate on the second problem. There are different varieties of OSR.[2] Here, the focus is

1 Given that the very notion of scientific realism is multi-faceted (Chakravartty, 2017; Chakravartty, Van Fraassen, 2018; Rowbottom, 2019), let us settle, for now, for an oversimplified, general understanding of this position: our best scientific theories allow for knowledge of the unobservable aspects of reality; i.a. it is reasonable to believe in the ontologies of such theories. I will return to more detailed considerations about scientific realism in the conclusions.

2 The position itself was proposed by James Ladyman (1998), and although he collaborated with Steven French (2003), the mature views of these two authors eventually differ

placed on the views of Steven French, who defends an eliminative version of OSR[3] (henceforth: EOSR). Broadly, the central thesis of EOSR can be put this way: structures form the only category in a scientifically adequate fundamental ontology of the physical world; the category of objects should be eliminated. Accurate version of scientific realism should accommodate this thesis.

The solution to the second problem mentioned above plays such an important role in defending EOSR (French, 2020; Ladyman, 2007) that the argument formulated around this issue has been called the argument from metaphysical underdetermination (MUA). In French's work the main theory in the context of which metaphysical underdetermination is analyzed is quantum mechanics (QM) (French, 1998; French, Krause, 2006; French, 2014; 2019). The aim of MUA is to establish that from the fact that two views of elementary particles – as individuals or as non-individuals – are both compatible with QM and both of them are deeply flawed, we should infer the validity of the claim that the category of an objectless structure is the best candidate for our metaphysical picture of the fundamental, physical world (French, 2014, vi): "We need to recognise the failure of our best theories to determine even the most fundamental ontological characteristic of the purported entities they feature. It is an *ersatz* form of realism that recommends belief in the existence of entities that have such ambiguous metaphysical status" (Ladyman, 1998, 419-420). The idea then is to dissolve the dilemma between two views of particles by deciding to be realists about the *structure* underlying both interpretations and to imbue this structure with metaphysical significance.

to a great extent (see: Ladyman, Ross *et. al.*, 2007; French, 2014) and should be considered separately. There are also moderate versions of OSR (Lam, Esfeld, 2012).

3 Of course, the structuralist views discussed herein form a group of positions different from the concepts linked to structuralism in ethnology or anthropology (which bring to mind Ferdinand de Saussure), or those linked to the strictly methodological analysis of scientific theories (e.g. Stegmüller, 1976).

My main objective in this paper is to scrutinize the metaphysical thesis of EOSR on the basis of critiques levelled against MUA. I argue that MUA consists of two underlying strategies, both of them having certain downsides which I illustrate. Finally, in the conclusions I argue that EOSR can be formulated without a metaphysical thesis, but the results are not satisfactory – especially since this would render the position not an *ontic* version of structural realism.

In section 2, I reconstruct the metaphysical thesis of EOSR and the MUA. In section 3 I present two main criticisms of MUA, formulated by Juha Saatsi (2010), Brading, Skilles (2012), and Mauro Dorato (2016). I show that these criticisms are mutually incompatible and I explain this fact by proposing that they are built in response to different "underlying strategies" in the original, informal MUA. In section 4 I analyze both strategies, now disconnected from the critiques considered, and show why they do not bring positive results in defending the metaphysical thesis of EOSR. I argue that according to the first strategy the metaphysical underdetermination of QM brings about EOSR, while according to the second strategy EOSR provides the best way of dissolving the metaphysical underdetermination of QM. I argue that the first strategy is questionable since, as it will turn out, it relies on EOSR being "the middle way" between two contradictory views of particles. I show why this is misguided. Furthermore, I claim that we are not forced to accept the second strategy, since the technical aspects behind it – symmetries of QM – can be understood as not being about the objecthood of quantum particles. In the conclusions I dismiss the metaphysical thesis of French's EOSR and show how his views can be characterized by epistemic and semantic theses. Here I will utilize a general schema for scientific realisms contributed by Darrel P. Rowbottom (2019).

2. INTRODUCING ELIMINATIVE ONTIC STRUCTURAL REALISM (EOSR)

EOSR is usually presented as a metaphysical thesis (Chakravartty, 2007; Ainsworth, 2010; Frigg, Votsis, 2011; Lam, Esfeld, 2012; McKenzie, 2017; Rowbottom, 2019; Benitez, 2023). French himself heavily supports this mode of exposition since he believes that being a scientific realist requires, i.a., a commitment to a deep metaphysical picture of the world that goes beyond existence statements about physical entities ("there are electrons," "there are spacetime points and regions," *etc*.): metaphysical categories (of objecthood, properties, objective modalities, relations, *etc*.) are needed to better understand reality as described by (fundamental) science (French, 2019, 22). For the time being I shall restrict myself to metaphysical considerations.[4] In the conclusions I will introduce other theses comprising EOSR.

I reconstruct the main metaphysical thesis of EOSR in the following way:

EOSR (Metaphysical)	a. There exists the fundamental structure of the world understood as a net of relations without relata; b. The category of objects is to be eliminated entirely from the ontology of physical world.

To avoid confusion, I will use "EOSR" instead of "EOSR (Metaphysical)" for the majority of the text, and will signalize when I return to using "EOSR (Metaphysical)." For the primary source of the thesis above I point to the following excerpt: "… we start with the laws and principles 'presented' (on the surface as it

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4 Presenting EOSR as a metaphysical thesis also allows to differentiate it from non-ontic types of structural realism. In Worrall (1989), we may find a version of epistemic structural realism according to which scientific theories correctly describe, *via* their mathematical equations, the unobservable reality, but they do not grasp any "nature" of the referents of theoretical terms. This account has problems of its own, but I won't elaborate on this here (see: Psillos, 1999, 149-150).

were) by the theory, interpret these, at least minimally, in terms of relations and properties, but then resist the temptation to take that further metaphysical step and regard these last as possessed by (metaphysically robust) objects. In particular, the structuralist insists, there is nothing in the theory itself, or in the laws and principles as they are presented, that requires us to posit objects qua property possessors. On this view, these relations and properties are features of the fundamental structure of the world … and what we standardly designate as 'objects' are indeed mere nodes in this structure. In particular, elementary particles are not metaphysically robust objects under this perspective, but are reconceptualized structurally and represented by the relevant symmetry groups …" (French, 2014, 114).

Making an effort to add more clarity and conciseness, French claims that: "An example of a further attempt to outline the characteristics of such a notion of structure in terms of 'laws' and 'symmetries' in the context of OSR is as follows: … law statements express the network of relations, 'held together' by the symmetry principles which represent what is invariant in the network" (French, 2014, 264). The symmetry principles – represented as group-theoretical structures[5] – are especially emphasized (French, 2020, 17), as they are "underpinning quantum statistics" (French, 2014, 43). In the context of QM the symmetry principle is the permutation invariance (PI). PI can be regarded as the symmetry group PERM(X) of bijective maps acting on the set X (French, 2014, 35). With respect to particle systems, the action of PI is represented as the exchange operator acting on quantum states composed of *n* identical particles of the same type.

5 Group theory is concerned with certain algebraic structures – groups. A group is a set with an operation (satisfying certain constraints) acting on the set. Depending on the context, groups may have many different properties. In geometry, groups are considered as sets of transformations under which a geometric object remains invariant. Such groups are called "symmetry groups." In physics, symmetry groups describe features of a given physical system. Such symmetries that leave a certain property unchanged under the symmetric transformations are called invariance symmetries.

Under PERM(X) the labels attached to particles can be switched, which entails that such labels have no physical meaning. Given a certain quantum state composed of particles of the same type, permuting the particles produces an empirically indistinguishable state. As it is claimed in EOSR, due to PI all is left is the structure encoded by this fundamental symmetry principle, where any element of the group-theoretical description of the quantum-physical system is only a nod in the structure. Hence, there are no objects (French, 2014, 97). I will return to PI in section 4. French's views on scientific laws do not play a large role in discussing metaphysical underdetermination of QM, so I will not discuss them here.

How can the abovementioned picture be supported by an argument based on the metaphysical underdetermination of QM? First things first, however: let me notice that this is just one type of underdetermination of scientific theories, distinct in its usage by French, since, usually, underdetermination-based arguments are formulated against realistic positions. The "standard" underdetermination thesis refers to a relation between a scientific theory (or the whole body of knowledge) and empirical evidence (see: Psillos, 1999, 156). This thesis was famously formulated by Pierre Duhem (1954) in his analyses of physical science. Over a half of century later it was generalized by Willard Van Orman Quine (1951) to all types of knowledge. Since then, the thesis is known as the "Duhem-Quine thesis" (DQ). Roughly, DQ's main insight may be captured in the following way: "When we assert that scientific theory choice is underdetermined by evidence, we mean that evidence by itself cannot direct a scientist to accept or reject a theory" (Turnbull, 2018, 2). It is useful however to distinguish different versions of DQ (see Laudan, 1990). For simplicity I adduce a very basic typology of the DQ thesis. Weak DQ states that "single descriptive propositions are never tested in isolation; rather, empirical testing presupposes complexes or systems of sentences" (Boylan, O'Gorman, 2003), i.e. there is always a conjunction of the propositions in question, auxiliary hypotheses and background knowledge involved. Stronger DQ adds the possibility of modifying other parts of the mentioned conjunction in order to save the tested proposition from recalcitrant evidence: "No *descriptive* statement can be individually falsified by evidence, whatever the evidence may be, since adjustments in the rest of the system can always be devised to prevent its *falsification*" (Hesse, 1970, 195). The strongest DQ asserts that, in fact, any element of any body of knowledge may be saved in light of unfavourable evidence: "Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system" (Quine, 1951, 40). Having the differences between versions of DQ in mind, one can formulate a general argument against scientific realism based on the very idea of DQ: "Any theory positing unobservables has rivals that are equally supported by all possible observational evidence for that theory" (Devitt, 2002, 39). Thus, endorsing a belief toward any specific set of unobservable[6] entities seems arbitrary and uncalled for.

The *metaphysical* underdetermination appears when a specific theory (mainly a physical theory in the context of EOSR) is not capable of determining unequivocally the characteristics of the entities it postulated, in the sense that the "two distinct metaphysical packages … are consistent with the physics" (French, 2014, 37). This is not only about postulating unobservable entities as such; rather, it is about the fact that different metaphysical characteristics are compatible with the entities in question. In fact, metaphysical underdetermination

6 "The distinction here between the observable and the unobservable reflects human sensory capabilities: the observable is that which can, under favorable conditions, be perceived using the unaided senses (for example, planets and platypuses); the unobservable is that which cannot be detected this way (for example, proteins and protons)" (Chakravartty, 2017). For the purposes of later discussion in this paper, it is important to note here that the notion of observables adduced is different from the technical notion of observables in QM. The notion of "observable" in QM is understood as a property of a system represented by an self-adjoint (Hermitian) operator on a separable complex Hilbert space, which assigns values to particular measurements. This notion of an observable is independent from the previous one.

was used in an argument against realism (Van Fraassen, 1989). As mentioned, however, French claims that an argument based on the metaphysical underdetermination of QM leads to EOSR.

The fact of metaphysical underdetermination in the context of QM stems from the following. It is claimed that QM seems to admit two mutually exclusive, yet equally valid, views of quantum particles, both of which assume that particles are a certain type of objects: either individuals,[7] or non-individuals.[8] To support this claim, French provides some examples. Firstly, he considers several accounts of particles as individuals. An example may be the view called "individuality + inaccessible states": "Indeed, it is sometimes claimed that such a view draws support from the very practice of experimental physics itself, with its individual tracks in a bubble chamber, distinct clicks from a counter and individual flashes on a scintillation screen. There may be problems with regard to issues of reference *etc.*, … but whatever the outcome of that particular philosophical discussion, quantum particles can be considered as individuals, just like classical particles, chairs, tables and people. This meshes very nicely with that very general approach to quantum mechanics which seeks to interpret the theory in terms that, ontologically speaking, differ as little as possible from classical mechanics (or, better, classical statistical mechanics). Thus it could serve as the underlying ontology of some sort of hidden variables approach in general or, more particularly, of the Bohm-Hiley interpretation, where you have individual particles

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7 We speak of an object as an individual when it has a well-defined and stable identity understood as a special relation that an object may have solely with itself, represented by the equal sign and noted formally as $a=a$. This relation is special in the sense that, according to the concept discussed, it occurs regardless of whether objects other than a exist or not.

8 We speak of an object as a non-individual object when it does not have a well-defined identity allowing to refer directly to it. Instead, it is rather that such non-individuals may form a certain (quasi-)set that remains identical despite a change of the positions of its (indistinguishable) elements (see: French, Krause, 2006; Arenhart, 2013).

chugging along well-defined spatio-temporal trajectories…" (French, Krause, 2006, 149).

The view of elementary particles as non-individual entities is treated by French as a standard view in quantum physics. He supports this belief by referring to Niels Bohr's account, according to which "… the new quantum statistics find no unambiguous application within the scope of ordinary statistical mechanics in which the existence of the action quantum is neglected and the particles are treated as *individual* dynamical entities" (Bohr, 1985, 398). On this, French also cites Erwin Schrödinger: "It seems almost ludicrous that precisely in the same years or decades which let us succeed in tracing single, individual atoms and particles, and that in various ways, we have yet been compelled to dismiss the idea that such a particle is an individual entity which in principle retains its 'sameness' forever. … And I beg to emphasize this and I beg you to believe it: It is not a question of our being able to ascertain the identity in some instances and not being able to do so in others. It is beyond doubt that the question of 'sameness,' of identity, really and truly has no meaning (Schrödinger, 2014, 121-122).

The metaphysical underdetermination argument (MUA) was first presented by James Ladyman: "We need to recognize the failure of our best theories to determine even the most fundamental ontological characteristic of the purported entities they feature. It is an *ersatz* form of realism that recommends belief in the existence of entities that have such ambiguous metaphysical status. What is required is a shift to a different ontological basis altogether, one for which questions of individuality simply do not arise. Perhaps we should view the individuals and nonindividuals packages, like particle and field pictures, as different *representations* of the same structure" (Ladyman, 1998, 419-420).

French accepts this basic characterization of the problem (French, 2014: 34). I propose the following reconstruction of the MUA:

Metaphysical Underdetermination Argument (MUA)	1. Interpreting quantum particles as objects (individual or non-individual), as recommended by standard realism, leads to metaphysical underdetermination. 2. Metaphysical underdetermination poses a problem for the realist, undermining his ability to provide an account of the most basic characteristic of the unobservable entities he advises to treat as real. 3. Thus, it seems best to abandon the category of objects altogether and search for another ontological option, which does not generate the metaphysical underdetermination problem. 4. EOSR is an ontological option for the realist that does away with objects, proposing an objectless structure of the world, encoded in symmetry principles underlying object-oriented views (of particles in the context of QM), as the correct metaphysical description of the physical world at the fundamental level. 5. Interpreting particles as some type of objects leads to metaphysical underdetermination; EOSR does not lead to this problem. 6. Hence, choosing EOSR over options relying on the category of objects seems to be correct.

Since there is a clear dichotomy between object-oriented and non-object-oriented ontologies, the MUA shows that EOSR is the better option. According to proponents of EOSR, the objectless structure interpretation of fundamental physics does not riddle us with metaphysical underdetermination, whereas the object-oriented ontology interpretation does.

3. CRITIQUES OF THE METAPHYSICAL UNDERDETERMINATION ARGUMENT (MUA) AND THEIR INCONSISTENCIES

MUA can be criticized in many ways (for general doubts about MUA, see: Chakravartty, 2003; Morganti, 2011). However, I think that the most important and specific critiques can be found in Saatsi

(2010); Brading, Skilles (2012); and Dorato (2016). Here we can find two distinct ways to counter the MUA. The first way, inspired directly by Saatsi (2010) was proposed in Brading, Skilles (2012). Let us label this critique CR1. It is based on a certain reconstruction of MUA:

"(P1) Object-oriented realists are committed to objects (that are ontologically basic) having determinate *individuality profiles*: (i) there is a fact of the matter about *whether* an object is an individual or not, and (ii) if it *is* an individual, there is a fact of the matter about how, precisely, it is individuated.

(P2) If (P1) is the case, then adopting object-oriented realism commits us to expecting that our best theories will accurately describe what these individuality profiles are like.

(P3) But our best theories fail to offer individuality profiles for their purported objects (much less describe precisely what they are): the individuality status of these objects, as given by our best theories, is *metaphysically underdetermined*.

(C1) So object-oriented realism is (probably) false.

(P4) If OSR is true, then our best theories are not infected with metaphysical underdetermination.

(C2) So, all other things equal, OSR is preferable to object-oriented realism" (Brading, Skilles, 2012, 100-101).

Juha Saatsi's claim about the MUA is brief, as he states that "it seems that the structuralist proposal only makes matters worse, for with such an alternative structuralist ontology available there would be three instead of two to choose from" (Saatsi, 2010, 261). Katherine Brading and Alexander Skilles expand on this insight in the context of their reconstruction of the MUA. They interpret the discussion about the reconceptualization of objects in terms of the underlying structure, and about eliminating objects, as generating metaphysical underdetermination within the EOSR camp: in the first case objects are ontologically dependent on the fundamental structure, Although they are understood as "less real" than this structure, they still exist (this is called "reductive OSR"). In the second case, objects are eliminated from an ontology altogether (Brading, Skilles, 2012, 112). Having this in mind, they add the following steps to their reconstruction of MUA:

"(P5) If OSR is true, then there is a fact of the matter about whether objects exist or not.

(P6) If (P5) is true, then we should expect our best theories to say whether objects exist or not.

(P7) But our best theories fail to say whether objects exist; whether they do or not is underdetermined by the interpretations offered by eliminative and reductive OSR.

(C3) So OSR is (probably) false" (Brading, Skilles, 2012, 112).

The above reasoning shows that metaphysical underdetermination applies to EOSR itself. Thus, it seems, a correct argument for OSR should not make reference to the metaphysical underdetermination of QM.

Mauro Dorato, who's critique of MUA I denote as CR2, arrives at a different result. He provides the following reasoning: "(1) Quantum physics underdetermines a choice between two metaphysics of individuality. (2) In order to overcome this unwanted underdetermination, we should embrace an ontology of structures that is common to the two metaphysical views (the first motivation in favour of OSR). (3) Contemporary physics and in particular the group-theoretical representations that underpin it favour OSR (the second motivation for OSR, supposed to be independent of the first). (4) OSR favours the priority of structures over individuals. (5) Premises 3 and 4 imply that contemporary physics favours the priority of structures over individuals. (6) Given 5, contemporary physics does not underdetermine the metaphysics of individuality, a fortiori in view of French's eliminativism about objects!" (Brading, Skilles, 2012, 174).

If the elimination of objects is derived from contemporary physics, it can be argued that the latter is not so much metaphysically underdetermined as *directly* leading to preferring the structuralist ontology. Metaphysical underdetermination cannot play a role in defending EOSR – especially: EOSR cannot be derived from it – since the very concept of metaphysical underdetermination, according to Dorato, begs the question if we agree that contemporary physics favors group-theoretical structures (symmetry principles).

To recapitulate: according to Saatsi's, Brading's and Skilles' critique, MUA does not support EOSR because its internal logic leads to underdetermining this very position. In Dorato's critique, the MUA does not support EOSR because its internal logic leads to denying that fundamental physics is metaphysically underdetermined.

CR1 and CR2 are clearly mutually exclusive. One could brush this fact aside as a simple consequence of the vagueness in the original presentation of the MUA. One could interpret this incoherence as evidence that, no matter how we decide to reconstruct the MUA – clearly, the conclusions in CR1 and CR2 are different because the reasoning they are based on is different – EOSR ends up unsupported by it. I think these are valid responses to the incoherence shown. At the same time, it seems that there is more to the story.

I claim that the main source of the incoherence lies in the fact that the original, informal MUA admits at least two understandings, which result from two "underlying strategies" in the MUA, and that CR1 and CR2 are formulated as responses to such different strategies. The latter arise, I claim, because of the ambiguity of the relation between metaphysical underdetermination and EOSR. On the one hand, it seems that metaphysical underdetermination is viewed as bringing about EOSR – I will refer to this as "strategy1." In CR1, MUA seems to be understood according to this strategy due its focusing on the underdetermination in question. On the other hand, one could understand the MUA as an argument according to which we should endorse EOSR, since it prevents the metaphysical underdetermination that is a problem for realism – I will refer to this as "strategy2." CR2 apparently follows this strategy, since it emphasizes the group-theoretical aspect in the formulation of EOSR. In the case of strategy1, EOSR is formulated *in virtue of* metaphysical underdetermination; in the case of strategy2, the formulation of EOSR is based on independent considerations leading to the possibility of dissolving the underdetermination in question. In strategy1, the metaphysical underdetermination of QM is understood as pointing at the symmetry principle underlying both object-based interpretations of quantum particles. Strategy2 seems to be more about a *specific way* of dissolving metaphysical underdetermination, if we were to admit that it occurs because of the assumptions about objecthood in quantum particles.

The ambiguity regarding the underlying strategies in MUA is also present in my reconstruction of the argument. Strategy1 can be found in premises (1) – (4), while strategy2 in premises (4) – (6). They clearly overlap and so my reconstruction allows the strategies to coexist. Nevertheless, I think the question remains: should we adopt EOSR because the metaphysical underdetermination of QM points towards it (strategy1), or rather because this position allows us to solve the problem of metaphysical underdetermination (strategy2)? The difference between strategy1 and strategy2, however subtle, lies mainly in these motivations. Do we start by observing that QM is metaphysically undermined with respect to the objecthood of particles, and so we need a different account formulated without the category of objects? Or do we start by formulating EOSR in terms of certain physical structures and afterward we utilize this account to escape the underdetermination in question? The point is that a critique of MUA should not leave any strategy outside its scope. Criticism in which the MUA is understood along strategy1 leaves open the possibility of relying on the idea that EOSR is the problem-solver for metaphysically underdetermined QM, i.e. strategy2. Criticizing MUA solely through strategy2 allows the proponent of EOSR to retort to the importance of providing, in Ladyman's words, a non-*ersatz* form of realism, one in which the question of individuality does not arise. Such a form of realism is pointed at from the vantage point of metaphysical underdetermination – this point of view underpins strategy1.

4. SCRUTINIZING THE STRATEGIES

The two strategies uncovered above can be examined independently of CR1 and CR2. In this section I will address the downsides of both strategies. From this perspective the MUA will be deemed as unsatisfactory. In strategy1 one finds motivation for metaphysical underdetermination in the very formulation of the main metaphysical thesis of EOSR in terms of objectless, group-theoretical structure, supposed to be shared by object-oriented interpretations of QM. The main reason to doubt strategy1 stems from the purported fact of metaphysical underdetermination itself. According to French, this underdetermination obtains because of the presuppositions about the ontology of objects upon which the views particles-as-individuals and particles-as-non-individuals are built on. Now, what if one view is actually better than the other? This would prompt the suggestion that if QM is metaphysically underdetermined then it has nothing to do with the category of objects, and so the need that a metaphysics of quantum particles rely on an objectless, pure structure is uncalled for.

French took into account and attempted to break the metaphysical underdetermination by arguing for one view over another. He presented this, however, in a specific manner. He claims that both views can be defended despite the fact that both have flaws owing to their relying on the category of objects. Thus, trying to dissolve the metaphysical underdetermination in this way results in a hopeless tug-of-war. Firstly, "… we might 'break' the underdetermination by considering how the particles-as-individuals package might be further supported. Typically, those who wish to restrain their metaphysical commitments when it comes to individuality have appealed to some form of the Principle of Identity of Indiscernibles (PII) in order to ground this individuality on some property of the objects concerned.

… However, the approach based on PII has recently been revived with the claim that a relevant sense of individuality can be grounded in a notion of 'weak' discernibility applicable to quantum particles… . The central idea is to admit relations within the scope of PII and then to note that fermions in, for example, a singlet state can be weakly discerned via irreflexive relations such as 'has opposite spin to.' This weak discernibility can then ground a 'thin' form of objecthood that could then be invoked by the object-oriented realist" (French, 2014, 39).

The downside of this approach, as French claims, is that the Principle of Identity of Indiscernibles in its weak version[9] merely allows for the numerical plurality of objects, which is too little to ground their robust distinctiveness, as the proponent of the particles-as-individuals view would prefer (French, 2014, 39). Alternatively, one could deny that the version of the PII in question confers individuality solely in terms of irreflexive relations, for these, according to French, need to presuppose the identity of their relata, the very thing they are set to establish (French 2019, 15). In his choice of options for preferring the particles-as-individuals view, French also refers to Bohm's interpretation of QM, called Bohmian Mechanics (BM), as already mentioned (French, Krause, 2006, 149). I will return to BM shortly.

When it comes to trying to resolve the metaphysical underdetermination by employing the particles-as-nonindividuals view, French claims that this perspective may be considered as more convincing "on the grounds that it meshes better with quantum field theory (QFT),

9 The standard Principle of Identity of Indiscernibles states that "if, for every property F, object x has F if and only if object y has F, then x is identical to y" (Forrest, 2020), which means that if two objects share the same set of (monadic) properties then those objects are one and the same object. In its contrapositive form, the Principle of Identity of Indiscernibles states that if object are distinct they must differ in their (monadic) properties. A weak version of this principle (Quine, 1976; Saunders, 2003; Hawley, 2009; Arenhart, 2013) in its contrapositive form states that objects are always discernible, some of them however only in virtue of some irreflexive relations they stand in, e.g. two perfect spheres separated by a one mile; each sphere is a mile from the other, but none of them is one mile from itself (Black, 1952).

where particle labels are simply not assigned right from the start… . In effect this is another appeal to the heuristic fruitfulness of one 'horn' of the underdetermination over the other. It is also a retrospective move, in so far as, having QFT to hand, we know now that there is such meshing, so it is not a mere promissory note" (French, 2014, 41). French's rebuttal of this argument rests on denying the QFT any significant role in resolving philosophical problems about a different theory – QM (French, 2014, 41). However, French's earlier objection utilizes QFT in a positive manner. French claimed that if (quantum) fields may transfer energy, it means they are real in a concrete and physical sense, because, if we are to seek in physics any equivalent of substantiality as traditionally understood, it would be precisely the ability to receive and transmit energy. In this sense, fields would be "concrete" and "substantival," and so they would qualify as individual physical entities. Therefore, fields may be understood as determined entities, in the light of which the concept of non-individuals is inadequate (French 1998). The point of discussing these options is to emphasize "the motivational force of the underdetermination in pushing us to avoid all the above philosophical 'to and for' and to drop the commitment to objects to begin with" (French, 2020, 16).

Though French is reluctant in some places to connect the question of objecthood of quantum particles with certain interpretations of QM, in his main exposition of EOSR (French, 2014), he refers, as I noted earlier, to Bohmian Mechanics as an interpretation of QM in which one can find support for the particles-as-individuals view, which, ultimately, he seems to endorse (French, 2014, 96, footnote 62; French, Krause, 2006, 149). In my opinion this connection is reasonable insofar as one can find in BM the most straightforward way to treat quantum particles as individuals. Following this path, however, seems to undermine the assumption that both the particles-as-individuals and particles-as-non-individuals views are equally compliant with QM.

According to BM, "all particles possess well-defined trajectories and that measurements of various observables ultimately reduce to measurements of the location of an object within its guiding pilot wave" (Bigaj, 2022, 206). Localization at a position may serve in this context as a property which individualizes a quantum particle (Brown *et al.*, 1999). An approach of this type, however, may be questioned, and with it the particles-as-individuals view. The essential difficulty of BM may be expressed as follows: "Contrary to the common belief that in (Bohmian mechanics) an accurate measurement of a particles' position is "simply" its detection …, it is often not so: what is the result of pseudo-measurements of position in standard QM often does not concur with the positions of particles in the Bohmian sense, which in such cases, as a principle, are not even observable…" (Woszczek, 2018, 73). This alone may be a cost too high – especially if the goal would be just to defend a certain view on objecthood in quantum particles. The difficulties with BM do not stop here. One could further mention the problem of combining BM with special relativity, which is important when it comes to formulating QFT (Hoefer, 2020, 28) or the less known problem of semiclassical systems described by BM. Semiclassical systems are such excited quantum systems whose "properties … are seen to depend on certain properties of the corresponding classical system" (Matzkin, Nurock, 2008, 18). BM's description of particles' trajectories should fit the classical description. However, this is not the case. There is a "dynamical mismatch [which] induces a tension between the supposedly real dynamics of the particles (following de Broglie-Bohm trajectories), the statistical distribution of the particles (determined by the underlying classical properties) and the classical trajectories (observed by means of a physical interaction)" (Matzkin, Nurock, 2008, 37). The problems mentioned do not target directly the individuality of quantum objects, but they do challenge to some extent the BM interpretation, which, as pointed out, is the most promising framework for envisaging particles as individuals.

The conclusion of this brief criticism of BM is that, to the best of my knowledge, the view of particles-as-non-individuals is not burdened as much. Thus, it seems to be the better option. It will turn out that QM is not metaphysically underdetermined because the two object-oriented approaches to particles are not equivalent – we can keep the category of objects if it is properly understood. If we take EOSR for granted and accept the criticism of the particles-as-individuals view, we can formulate a simplified version of Saatsi's objection: the only available underdetermination occurs *between non-individual objects and the account of EOSR in which objects are eliminated completely*. In this scenario, premise (1) of my reconstruction of MUA is undermined and so the rest of the argument cannot be carried out. However, there is no reason to rely solely on the category of an objectless structure to formulate a viable metaphysics of the quantum realm.

The last point is important since it challenges French's short response to Saatsi: "Saatsi has argued … that OSR simply presents us with a third horn and thus exacerbates the underdetermination. I disagree, since I maintain that OSR accommodates the common core of the competing 'particles-as-individuals' and 'particles-as-non-individuals' horns via its focus on group structure" (French, 2014, 43). Accommodating the common core of the two views is misleading, however, if those views are, in fact, not competing – in the sense of not being on the same footing. This shows that strategy1 is inadequate in defending EOSR since, firstly, it is simply too dependent on the equivalence of the two views of particles, and, secondly, strategy1 too heavily emphasizes the intermediary nature of EOSR. This is too little to support the EOSR-ist view of quantum particles.

Turning to strategy2, one could dismiss it on the basis of the critique of strategy1, which ruled out the possibility of EOSR resolving metaphysical underdetermination. However, since strategy1 and strategy2 are distinct, there are independent reasons to doubt strategy2. Here, metaphysical underdetermination of QM would be solved in virtue of the metaphysical significance of permutation invariance (PI). If we bracket the critique of strategy1, we may directly investigate the line of defense in strategy2: does EOSR with its emphasis on PI really solves the problem of metaphysical underdetermination, when this problem is viewed as an issue about objecthood (French, 2014, 19)?

To recall French's view on the fundamental objectless structure of the world: this structure should be understood as a combination of laws of nature and symmetry principles, where "law statements express the network of relations, 'held together' by the symmetry principles which represent what is invariant in the network" (French, 2014, 264). The symmetry principle in the context of QM is PI. According to French, PI has a certain "modal" sense: "As for the role of PI, the principle itself is regarded as a feature of the structure of the world and describing this role in terms of its acting as a kind of initial condition imposed on the world is simply a way of saying that the structure of the world is like this, rather than that, where 'that' will refer to worlds (not, presumably, physically possible) where the states of an assembly of particles are not so constrained" (French, 2014, 269). By "like this" a very fundamental fact is meant, namely that the action of the PI can produce certain restrictions on the set of possible types of particles: bosons and fermions (French, 2014, 36). Mathematically, this is represented by a partition of a certain complex Hilbert space (a vector space with an inner product satisfying particular conditions. In the quantum-mechanical context, a Hilbert space is interpreted as a state space which enables to specify possible states of the quantum system) to symmetric and anti-symmetric subspaces, which correspond to the two types of particles mentioned (bosons and fermions, respectively). Other possible subspaces are available; however, they seem not to be actualized (Bigaj, 2022, 48). French's "modal" interpretation of PI consists in the claim that PI allows for what is fundamentally possible in the physical world. In turn, this relies on the division between bosons and fermions – on the type-related indistinguishability of particles (considered here in the context of state-independence[10]), which leads to denying them objecthood (French, 2014, 144, 166, 269; 2019, 27).

If the metaphysical underdetermination of QM is understood as a problem about objecthood, then EOSR presumably brings about the dissolution of this problem by dissolving objects in virtue of PI – as strategy2 would go. Though one could be concerned about the notion of a "feature of the structure of the world" attributed to PI (which clearly raises the question about the definition of an ontologically fundamental structure, and what does it actually mean to be a feature of this structure) or about the now standard objection against EOSR regarding the unintelligibility of the notion of relations without relata[11] (Busch, 2003, 214; Chakravartty, 2003, 871), I would like to highlight another issue.

Usually, two postulates are distinguished in the context of the abovementioned functions of PI – the Indistinguishability Postulate (IP) and the Symmetrization Postulate (SP). To put it briefly, IP "stipulates that the expectation values for physically meaningful operators be the same for all permuted states" (Bigaj, 2022, 22). It is empirically established that the states of quantum systems composed of particles of the same type remain the same if permuted (Glick, 2016). Omitting technical details here (for proofs see: Bigaj, 2022), there are two ways to interpret IP: "as a condition imposed on the states available to systems of particles of the same type, or as a condition on the set of admissible observables" (Bigaj, 2022, 22-23). SP can be formulated as a claim that "For any system of particles of the same type, its states are either exclusively symmetric, or exclusively antisymmetric" (Bigaj, 2022, 24). Usually, IP and SP are presented

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10 If we consider particles in the context of state-dependence, we have to consider Pauli's exclusion principle, which states that two or more identical fermions cannot simultaneously occupy the same quantum state.

11 For the classic argument against EOSR in which it is claimed that this philosophy reduces the physical world to mathematical structure, see: Cao, 2003.

as intertwined: “Typically, the Symmetrization Postulate is argued for by reference to the Indistinguishability Postulate: the argument is that SP makes IP true, and this gives us a reason to adopt SP as a way to ensure the permutation-invariance of expectation values. But … we … know that the condition that observables be symmetric is by itself sufficient to make IP true, regardless of whether we impose any additional restrictions on the available states of same-type particles” (Bigaj, 2022, 26). The point is that we can consider SP as a postulate independent of PI and IP, even though there are arguments in favor of keeping SP (Bigaj, 2022, 53-59). French’s account of the metaphysical role of PI rests on the assumption that PI produces the state of affairs expressed in SP[12] (and, in the following step, IP). However, a different perspective is available: firstly, we may omit reference to SP entirely and, secondly, we can do this by focusing on certain restrictions placed on quantum observables.[13] This leads to the following reason to doubt strategy2 in defending EOSR. The fact that PI is central to EOSR does not, by itself, yield a lack of metaphysical underdetermination, understood as a problem about the objecthood of particles, because IP can be made true without any reference to “modal” restrictions imposed on the world by PI and without endorsing SP. Without abandoning the distinction between bosons and fermions, the whole story can be made about admissible quantum observables and not about the entire category of objects. The argument illustrated, ultimately, considers the terms used to articulate the role of IP, SP and PI in the context of MUA. In short, adopting PI as a “feature of the structure of the world” does not guarantee that this symmetry principle allows for any conclusions about the metaphysical underdetermination of QM.

12 Or, at least, explains SP and makes it non-ad hoc (French, 2014, 268).

13 See footnote 7.

5. CONCLUSION

In this article I identified and analyzed two strategies underlying the MUA. That we can distinguish such strategies was derived from the critiques of EOSR formulated by Saatsi, Brading, Skilles and Dorato. I argued that both strategies have certain disadvantages which cast doubts on the MUA as a whole. Strategy1, which amounts to the claim that the metaphysical underdetermination of QM leads to EOSR, proved problematic due to its reliance on the dubious equivalence of two object-oriented interpretations of quantum particles and on the assumption that EOSR gets the upper hand in virtue of its being formulated in terms of the structure underlying both interpretations. Strategy2, encapsulated in the statement that EOSR avoids the metaphysical underdetermination of QM, can be put under suspicion, as I proposed, by showing that PI, a crucial element of the metaphysical thesis of EOSR, can be understood as part of a story about admissible observables in the quantum realm, rather than about individuality profiles of quantum entities. If we agree that the troubles with the two strategies raise scepticism toward the MUA and if we recall that the MUA is supposed to be the main reason to adapt EOSR's metaphysical thesis, then we may claim that this thesis is undercut. Once we discard the metaphysical thesis of EOSR, is there anything left of this position? Actually, yes. However, the result is unsatisfactory, and in my concluding remarks I want to briefly explain why.

In section 2, I mentioned that EOSR contains more than just a metaphysical thesis. Given that this thesis may be rejected, we may ask whether the other theses of EOSR can hold their ground. Clearly, without EOSR (Metaphysical), French's views are not an ontic version of structural realism; the name of the position becomes obsolete. Leaving nomenclature aside, in engaging with this question I will utilize Darrell P. Rowbottom's (2019) general blueprint for realisms, consisting, first and foremost, of schemas of the semantic and epistemic theses of realisms:

(Semantic)	A proper subset of scientific discourse concerning unobservable entities, S, should be taken literally.
(Epistemic)	A proper subset of science's content, E, is approximately true (on a proper subset of theories of truth, T).

The blueprint for antirealistic positions may be viewed as follows (Rowbottom, 2019, 462):

(Semantic-)	A proper subset of scientific discourse concerning unobservable entities, S-, should not be taken literally.
(Epistemic-)	A proper subset of science's content, E-, is not approximately true (on a proper subset of theories of truth, T).

On the metaphysical thesis,[14] Rowbottom simply asserts that "reality is prior to thought" (Rowbottom, 2019, 461). Clearly, the metaphysical thesis of EOSR is more complex.[15] The abovementioned blueprint allows to define, from a realist standpoint, the core of the debate between realists and antirealists as "tackling the following questions:

14 Rowbottom distinguishes also the "methodological thesis" of realism, which, as he claims, is not central to realisms – it supports the epistemic thesis – but at the same time it cannot be dispensed with. The basic methodological thesis states that "[s]cientific methods reliably (or typically) select theories or models that are virtuous," and it is accompanied by a thesis on virtues: "Virtues are (typically) indicative of a degree, d, of truth-likeness or representational accuracy" (both quotations from Rowbottom, 2019, 467).

15 I propose the following formulation of a blueprint for the metaphysical thesis for realisms: "A proper subset of metaphysical discourse M concerning fundamental categories of objective being admits a connection with a proper subset of theories' content E." The way I proposed to reconstruct the metaphysical thesis of EOSR does not follow this schema rigorously, however.

what is S?; what is E?; and … what is T?" (Rowbottom, 2019, 461).[16] My reconstruction of the non-metaphysical theses of EOSR utilizing Rowbottom's schema is the following:

EOSR (Semantic)	Symmetry principles in a given theory should be taken literally, at least as descriptions of invariant quantities pertaining to unobservable entities.
EOSR (Epistemic)	Scientific models are partial representations of reality according to the partial structures approach to scientific theories; sentences referring to the information encoded in specific partial structures are quasi-true.

In the case of EOSR (Semantic) we could say that group-theoretical structures enable theories, to borrow from Saatsi's (2019a; 2019b) formulation of "minimal realism," to latch onto unobservable reality. In the case of EOSR, the most important theories would be theories of fundamental physics. Saatsi elaborates on the notion of "latching onto" in the following way: "*T* latches onto unobservable reality if and only if *T*'s degree of empirical adequacy is accounted for by *T* providing a veridical representation of some aspects of unobservable reality" (Saatsi, 2019b, 623). That French believes in the success-inducing role of symmetry principles in scientific theories is explicit (French, 2014, 147). Scientific progress and growing empirical adequacy may be explained, in a very broad scope, by the fact that invariant quantities of unobservable reality are captured *via* group-theoretical structures. If we agree with this outline of EOSR (Semantic), the main reason to be dissatisfied with it would be that without EOSR (Metaphysical), EOSR (Semantic) proves not that much innovative. A similar idea can be found independently in Rickles (2007) and Roberts

16 On the antirealists side this would mean "answering: what is S-?; and what is E-? In short, it concerns how to *partition* the space of discourse and the space of content into these sets" (Rowbottom, 2019, 461).

(2011). For example, Dean Rickles's „minimal structuralism" proposes a "… view whereby the observables are (gauge invariant) correlations between (gauge variant) quantities (i.e. correlata) that cannot be viewed as independent from the whole correlation: the correlata are measurable in virtue of the fact that the correlation is predictable and measurable. Thus, interpretively speaking, the structure comes before the individuals since the individuals are not measurable. … It is in this sense that they are structural, and – given the further claim that the observables give a true account of the world – the ontology based upon them is structural realist. It is minimal because it does not say that all there is this structure (Rickles, 2007, 215).

It would seem then, that EOSR (Semantic) primarily recommends such an account of scientific theories, where the parts of theories which latch onto reality are group-theoretical. This claim alone, however, is not sufficiently distinctive, even grouped with EOSR(Epistemic), if we wish to establish EOSR as a contender in the competition for the best version of realism.

EOSR (Epistemic) deals mainly with scientific models. To provide a very general outline of the concept of partial structures, it can be said that "the central idea is to extend the usual notion of structure, through the device of a family of partial relations, in order to model the partialness of information we have about a certain domain" (French, 2014, 102-103). Quasi-truth is a property of sentences referring to a properly defined partial structure which contains some information about a target system (Bueno, French, 2011, 860). Accommodating theoretical representations from the perspective of partial structures and quasi-truth is supposed to account for the incompleteness and openness of science (Arenhart, Krause, 2023, 125) and, in the context of the retention of theoretical content through changes in science, to allow, i.a., for capturing the structural content of consecutive theories through the supplementary concept of partial isomorphisms between structures in such theories, including group-theoretical structures (Costa, French, 2003, 125; French, 2014, 10).

A reason to be dissatisfied with EOSR (Epistemic) lies in the fact that utilizing the concepts of partial structure and quasi-truth fall under broad pragmatistic perspectives on scientific representation (French, 2019, 24). This may seem attractive for the realist, especially if he focuses primarily on the scientific method, but, as French admits, the concepts presented can be equally well employed by the anti-realist (French, 2019, 23). An example of an anti-realist position based on partial structures can be found in Bueno (1999). Furthermore, one can find a "methodological minimal scientific structuralism" (Brading, Landry, 2006; Landry, 2012), which does away with ontological commitments and focuses on the "shared structure" between theories, though structure, in this approach, is understood not only in terms of partial structures or partial isomorphisms, but also in terms of a category theory. Similarly to EOSR (Semantic), the idea behind EOSR (Epistemic) can be successfully formulated outside the perspective of French's EOSR.

As I have claimed in this paper, EOSR (Metaphysical) is doubtful due to the weakness of the MUA and EOSR can generally be formulated without it. We can remain agnostic with respect to the "deep picture" of the structure of the world and uphold EOSR (Semantic) and/or EOSR (Epistemic). However, these theses are not, so to speak, specific or strong enough to pick them over some of the competing claims. This can be especially confusing in the case of EOSR (Epistemic), where we cannot be sure whether there is actually any reason not to opt for the anti-realist usage of partial structures and quasi-truth if we do not accept EOSR (Metaphysical).

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