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# Ontic structural realism and quantum field theory: Are there intrinsic properties at the most fundamental level of reality?

Philipp Berghofer

Department for Philosophy, University of Graz, Heinrichstraße 26/6, 8010, Graz, Austria

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## ABSTRACT

Ontic structural realism refers to the novel, exciting, and widely discussed basic idea that the structure of physical reality is genuinely relational. In its radical form, the doctrine claims that there are, in fact, no objects but only structure, i.e., relations. More moderate approaches state that objects have only relational but no intrinsic properties. In its most moderate and most tenable form, ontic structural realism assumes that at the most fundamental level of physical reality there are only relational properties. This means that the most fundamental objects only possess relational but no non-reducible intrinsic properties. The present paper will argue that our currently best physics refutes even this most moderate form of ontic structural realism. More precisely, I will claim that 1) according to quantum field theory, the most fundamental objects of matter are quantum fields and not particles, and show that 2) according to the Standard Model, quantum fields have intrinsic non-relational properties.

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## 1. Towards the most tenable form of ontic structural realism

The question of whether the world we live in is adequately described by our most successful scientific theories is a central topic in the philosophy of science. There is a special focus on the ontological status of unobservable entities such as atoms, electrons, and quarks. Scientific realism propagates a positive attitude towards the existence of entities posed by science: We are not only justified but are obliged to believe in the existence of the entities posed by science, whether they are observable or not. The main motivation for this view is the miracle argument which quotes scientific realism as the best explanation for the obvious success of our scientific theories. This success would be miraculous if our successful theories were misleading. Despite their evident plausibility, both scientific realism and the miracle argument have been attacked on many fronts. Recently, however, a specific version of scientific realism has emerged that has been widely discussed and enjoys considerable popularity. This is structural realism. Structural realism supposes that science primarily tells us something about the structure of, or the relations within, the physical world. A distinction is made between epistemic (ESR) and ontic structural realism (OSR).

Modern ontic structural realism was introduced by Ladyman in 1998. Addressing Worrall's conception of structural realism (Worrall, 1989), Ladyman poses the question of whether structural realism is supposed to be metaphysics or epistemology. This distinction is often expressed as follows:

ESR: Structures are all we can *know*.

OSR: Structures are all there *is*.

By now, OSR comes in many different flavors, and the claim that all there is are structures is referred to as radical or eliminativist structural realism (ROSR). ROSR implies that there are no objects. Neither the particles your body is made up of, nor the chair you are sitting on really exist. To be sure, ROSRists do not deny that relations have relata, but they interpret these relata in structural terms.<sup>1</sup> This can mean either that it is, so to speak, relations all the way down (Stachel, 2006, p. 54) or that “while the objects are there, they are merely ‘points of intersection’ of the relations between them.”<sup>2</sup> (McKenzie, 2017, p. 5)

The literature most prominently features three motivations for (R)OSR. Perhaps most straightforwardly there are the “argument

E-mail address: [philipp.berghofer@uni-graz.at](mailto:philipp.berghofer@uni-graz.at).

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<sup>1</sup> For a defense of ROSR cf., e.g., French & Ladyman, 2003 and French, 2014.

<sup>2</sup> I want to thank an anonymous referee of this journal for drawing my attention to this distinction as it is spelled out in McKenzie, 2017.

from coherence” and “the argument from parsimony” (Esfeld & Lam, 2008, p. 46). The argument from coherence is based on the idea that, due to the lack of epistemic access to fundamental intrinsic properties, epistemology and metaphysics can only be coherent if one denies the existence of such intrinsic properties. Thus, the two crucial premises of this argument are as follows:

P1: “Our metaphysics should be coherent with our epistemology.” (Esfeld & Lam, 2008, p. 46)

P2: We have no epistemic access to fundamental intrinsic properties.

The argument from parsimony is based on the fact that the existence of relational<sup>3</sup> properties is unquestionable, whereas the existence of intrinsic properties is not.<sup>4</sup> From the popular claim that metaphysics should be as parsimonious as possible, it follows that if we *can* eliminate intrinsic properties from our basic ontology, then we *should* eliminate them. Thus, the argument can be phrased as follows:

P1: A plausible metaphysics can get along with relational properties only.

P2: A plausible metaphysics cannot get along with intrinsic properties only.

P3: Our metaphysics should be as parsimonious as possible.

C: We should not allow for intrinsic properties.

The third main motivation is the *argument of underdetermination*. The idea is that there are cases of underdetermination which cast doubt on the existence of objects but not on the existence of objective structures. Most popular are cases from quantum physics (cf. French & Ladyman, 2003), but there are similar claims of underdetermination with respect to the existence of spacetime points (cf. Bain, 2006).<sup>5</sup>

A fourth motivation I would like to add is what I call the *transcendental argument*. One of the most notorious problems in philosophy of physics is to provide an explanation for why mathematics is so successfully applied to the world.<sup>6</sup> If ROSR is true and the world basically is structures, the applicability of mathematics – often considered the “science of structures” (cf., e.g., Clark, 2008, p. 561) – should come as no surprise at all.

In the following, this paper will focus on and discuss a fifth motivation for OSR: the claim that contemporary physics proposes that at the most fundamental level of reality there are only

relational properties. As we shall see, this is not only a motivation for ROSR, but also for a moderate version of OSR in particular.<sup>7</sup> Obviously, opponents of OSR can turn the tables by arguing that contemporary physics tells us that there are (also) intrinsic non-relational properties at the most fundamental level of reality. This would entail a refutation of OSR. Currently, charge, mass, and spin of elementary particles are widely considered examples of intrinsic properties. In accordance with McKenzie (2016), the present paper reasons that our currently most sound scientific framework for elementary particle physics – quantum field theory – tells us otherwise. Furthermore, it ought to be pointed out that according to quantum field theory, the most fundamental physical entities are quantum fields and not particles. This is often ignored or neglected by physicists and philosophers of physics (including McKenzie, 2016). In the following, it will be demonstrated that quantum fields *do* have intrinsic properties, which amounts to a refutation of OSR even in its most moderate form.<sup>8</sup>

Before unfolding the argument, some more obvious objections to *radical* OSR ought to be pointed out. Much of the ROSR criticism has focused on how there could be relations without non-structural relata (for an overview cf. Ladyman, 2016). However, what I take to be the main disadvantage of ROSR is its highly counter-intuitive eliminativist consequences that:

(1) Ordinary objects do not exist.<sup>9</sup>

(2) Particles do not exist.

Considering the radicality of this eliminativist view, it comes as no surprise that many researchers sympathetic to OSR have opted for a more moderate approach.<sup>10</sup> Most notably, Esfeld and Lam have argued for what they call moderate OSR (MOSR). Its basic idea is that there is no “ontological priority,” but that objects and relations “are both on the same footing, belonging to the same ontological ground floor.” (Esfeld & Lam, 2008, p. 31) As such claims are rather vague, the best way to define MOSR might be in terms of a denial of intrinsic properties. “Moderate structural realism proposes that there are objects, but instead of being characterized by intrinsic properties, all there is to the basic physical objects are the relations in which they stand.” (Esfeld & Lam, 2008, p. 31)

Does this mean that there are no intrinsic<sup>11</sup> properties whatsoever? Esfeld and Lam clarify: “The intrinsic properties that are at issue in the debate about structural realism are fundamental intrinsic properties of basic physical objects, sometimes referred to as intrinsic essences—that is, intrinsic properties that cannot be traced back to more fundamental properties.” (Esfeld & Lam, 2008, p. 28) Ladyman, accordingly, defines MOSR as follows: “There are individual entities but they don’t have any *irreducible* [my emphasis] intrinsic properties.” (Ladyman, 2016, section 4)

Thus, we should distinguish the strong claim that

<sup>3</sup> In this paper, I contrast intrinsic with relational properties not because I identify relational properties with extrinsic properties (= non-intrinsic properties) but because OSRists claim that objects only have relational properties. Thus, strictly speaking, when OSRists deny that objects have intrinsic properties, what they deny is that objects have intrinsic non-relational properties (this is because certain properties such as a cupboard being higher than wide can be both intrinsic and relational).

<sup>4</sup> As Marshall and Weatherston point out, “there is much less agreement about which properties are intrinsic.” (Weatherston & Marshall, 2014, section 1) For instance, it is often taken for granted that charge, mass, and spin of elementary particles are intrinsic properties. As I will show in section 3, this is not true.

<sup>5</sup> A common argument for structuralism, which is only applicable to spacetime structuralism, is the fact that spacetime structuralism can avoid the infamous hole problem. For a critical discussion cf. Wüthrich, 2009.

<sup>6</sup> As Wigner has famously said: “The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve.” (Wigner, 1960).

<sup>7</sup> Notice that while one of the original main motivations for epistemic structural realism was that it can avoid the argument from pessimistic meta-induction (cf. Ladyman, 2016), motivations for OSR often depend on taking the currently most successful physics seriously. Examples of this later strategy are Lam & Esfeld, 2012 and McKenzie, 2016.

<sup>8</sup> It is to be noted that the claim that our currently best physics supports OSR has become the main motivation for OSR. “While structuralist philosophies have resurfaced periodically under a variety of motivations, the chief selling point of OSR today is its claim to be the metaphysic most befitting of 21st century physics.” (McKenzie, 2017, p. 1) The present paper can be viewed as a critical evaluation of this claim.

<sup>9</sup> For a defense of this highly counter-intuitive claim cf. French, 2014, section 7. For a recent and powerful argument for the existence of ordinary objects cf. Thomasson, 2007.

<sup>10</sup> Esfeld and Lam point out that “metaphysics should not be more revisionary than is required to account for the results of science, and in that respect, we do not see a cogent reason to abandon a commitment to objects.” (Esfeld & Lam, 2011, p. 148).

<sup>11</sup> Since properties can be both intrinsic and relational.

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