A proposal for a minimalist ontology

Michael Esfeld
University of Lausanne, Department of Philosophy
Michael-Andreas.Esfeld@unil.ch

(final version 29 April 2017)
(forthcoming in *Synthese*, special issue "New trends in the metaphysics of science")

Abstract

This paper seeks to answer the following question: What is a minimal set of entities that form an ontology of the natural world, given our well-established physical theories? The proposal is that the following two axioms are sufficient to obtain such a minimalist ontology: (1) There are distance relations that individuate simple objects, namely matter points. (2) The matter points are permanent, with the distances between them changing. I sketch out how one can obtain our well-established physical theories on the basis of just these two axioms. The argument for minimalism in ontology then is that it yields all the explanations that one can reasonably demand in science and philosophy, while avoiding the drawbacks that come with a richer ontology.

Keywords: minimalist ontology, parsimony, Humeanism, relationalism about space-time, ontic structural realism, classical mechanics, quantum physics, Bohmian mechanics

1. Formulating a minimalist ontology

Any form of a naturalistic metaphysics uses science, notably fundamental physics, as the guide to ontology. However, one cannot read off the ontology from the mathematical structure of a physical theory. The first and foremost purpose of such a structure is to obtain a simple and informative representation of the evolution of a given domain of entities. The mathematical structure uses whatever parameters are appropriate to achieve that aim, but these parameters do not thereby automatically become part of the ontology of the theory. To mention just one prominent example, consider the wave function, which is the central mathematical innovation of quantum physics. It is without doubt a parameter that fulfils the mentioned purpose, but there is an ongoing dispute about what, if any, its ontological significance is. Thus, even if one endorses scientific realism and adopts a naturalistic stance in metaphysics, philosophical argument is called for to develop a proposal for an ontology of a given physical theory, or physics *tout court*.

One way to approach ontology is to draw a distinction between what can be called the *primitive ontology* of a given physical theory and what is its *dynamical structure*. The primitive ontology are those entities that, according to the theory, exist simply in the world. The dynamical structure of a physical theory then is made up by all those parameters that are introduced through their function for the evolution of those entities that constitute the primitive ontology. Note that this notion of a primitive ontology is much wider than the sense in which this term is used in the debate about the foundations of quantum mechanics (see Dürr et al. 2013, p. 29 (first published 1992), and Allori et al. 2008): a primitive ontology in this wide sense does not necessarily have to consist in entities that are localized in three-dimensional space or four-dimensional space-time (and what about space or space-time themselves?). Nonetheless, the paradigmatic example of a primitive ontology is this one: according to Newtonian classical as well as Bohmian quantum mechanics, point particles localized in three-dimensional space are what simply exists. Parameters such as momentum and gravitational mass in Newtonian mechanics as well as the wave function in Bohmian quantum mechanics then are central elements of the dynamical structure, because they are introduced in terms of their function for the evolution of the particle configuration.

In a second step, one can move on from the primitive ontology of a given theory to primitive ontology *tout court*, that is, seek to work out a proposal about what the entities are that simply exist in the world, given our best physical theories. The rationale for doing so is that naturalistic metaphysics strives for an ontology of the natural world that is not relative to particular physical theories. One may even go as far as claiming that it is inappropriate to speak of the ontology of this or that theory. Ontology is about what there is. It goes without saying that our access to what there is comes through the representations that we conceive in terms of physical theories. But this does not imply that ontology is relative to particular theories, because it is misguided to seek to infer ontology from the mathematical structure of physical theories. In other words, the idea is to search for an answer to the following question: What is a minimal set of entities that form an ontology of the natural world, given our well-established physical theories?

Consider how Jackson (1994, p. 25) describes the task of metaphysics:

> Metaphysics, we said, is about what there is and what it is like. But of course it is concerned not with any old shopping list of what there is and what it is like. Metaphysicians seek a comprehensive account of some subject matter – the mind, the semantic, or, most ambitiously, everything – in terms of a limited number of more or less basic notions. In doing this they are following the good example of physicists. The methodology is not that of letting a thousand flowers bloom but rather that of making do with as meagre a diet as possible.

This paper is concerned with formulating a proposal for "as meagre a diet as possible" when it comes to the ontology of the natural world. Of course, parsimony cannot be the only criterion. Coherence and empirical adequacy are further criteria that have to be satisfied. The latter includes being in the position to tell a story how the established physical theories can be construed on the basis of such a minimalist ontology.

In this section, I set out the proposal for a minimalist ontology in as general and as precise a manner as possible on a few pages. In the next section, I point out how this proposal is able to cover all established physical theories, from classical mechanics to relativistic physics and quantum physics, including quantum field theory. The remarks in that respect have to be quite sketchy and refer the reader to other published work, given the limited scope of a single paper. The aim of this paper is to make a case for minimalism as methodology in the metaphysics of science. In this vein, the third section gives an argument why minimalism is capable of yielding all the explanations that one can reasonably demand in science and philosophy. A brief conclusion then sums up the case for a minimalist ontology.

The foremost reason for singling out parsimony as the primary criterion for ontology is that for any candidate entity stemming from science – or common sense, or intuitions –, we need an argument why one should endorse an ontological commitment to that entity. Its being part of what is minimally sufficient to obtain an ontology of the natural world that is coherent and empirically adequate is the best argument for an ontological commitment. Given our cognitive situation, what we can strive for is minimal sufficiency, but not necessity or *a priori* knowledge when using parsimony as a guideline for the ontology of the natural world. The argument for not going beyond parsimony in one's ontological commitments then is that it is an illusion to think that by enriching the ontology, one achieves explanations that are deeper than those that a parsimonious ontology can yield; one thereby runs only into artificial problems and impasses, as I shall argue in section 3.

How can we set up such a parsimonious ontology? A first consideration is that in order to have a chance of being empirically adequate, a parsimonious ontology still has to endorse a plurality of objects. The objects better be simple for the ontology to be parsimonious, but there has to be a plurality of them. Even if one defends the view known as priority monism (Schaffer 2010b) – that is, the ontological priority of the one entity that is the whole universe –, one has to include an internal differentiation of the one whole into a plurality of objects. This implies that there are fundamental relations that carry out that internal differentiation (Schaffer 2010a). If relations have to be recognized anyway (*pace* Heil 2012, ch. 7, and Lowe 2016), one can employ them to individuate simple objects (that is, objects that do not have parts or any other internal structure). The numerical plurality of these objects then is not a primitive, but derives from the relations that individuate them. In consequence, I take the following two statements of ontology to be equivalent: (a) There is one whole (i.e. the universe) exhibiting an internal differentiation in terms of relations that individuate a plurality of simple objects within the whole. (b) There are relations that individuate simple objects so that the relations and the objects make up a configuration that is the universe. In the following, I shall prefer the vein of the latter formulation, relying on the relational holism conceptualized in Pettit (1993, ch. 4) and Esfeld (1998). The decisive issue is that the objects are not independent of each other, but individuated by relations.

Generally speaking, one can conceive different types of relations making up different sorts of worlds. For instance, one may imagine thinking relations that individuate mental objects making up a world of Cartesian minds. Lewis's hypothetical basic relations of like-chargedness and opposite-chargedness, by contrast, would not pass the test, since, as Lewis (1986b, p. 77) notes himself, these relations fail to individuate the objects that stand in them as soon as there are at least three objects. When it comes to the natural world, the issue are relations that qualify as providing for extension, at least if one follows Descartes' argument that extension is indispensable in an ontology of the natural world (*Principles of Philosophy*, book II, §§ 4-5). In any case, relations providing for extension – that is, distances – are, given the state of the art in both physics and philosophy, the first choice for an ontology of the natural world that is to be empirically adequate. To put it differently, no one has hitherto worked out a proposal for another type of relations than distances that could (a) do the trick of individuating simple objects and (b) be empirically adequate. The situation may change in a future theory of quantum gravity. However, as things stand, we are quite far from a physical theory of quantum gravity that includes matter and that is empirically adequate in providing a link with experimental data (measurement outcomes).

Hence, one axiom of our envisaged minimalist ontology has to introduce relations that individuate simple objects. But this is not sufficient, since the universe is not static. To achieve empirical adequacy, we need a second axiom that introduces an evolution of the configuration defined by the first axiom. In Cartesian terms, we need not only extension, but also motion. The simplest way to do this is to stipulate that the relations admitted as basic change. We thus get to an ontology that is defined by the following two axioms, and only these axioms:

(1) *There are distance relations that individuate simple objects, namely matter points.*

(2) *The matter points are permanent, with the distances between them changing.*

The claim of this paper is that these two axioms are minimally sufficient to formulate an ontology of the natural world that is empirically adequate. To stress again, the issue is minimal sufficiency. There is no claim about these axioms being necessary or *a priori*. They are fallible.

Indeed, these axioms are conceived in an empiricist vein, albeit not a positivist one. The empiricist vein consists in insisting on the fact that all the experimental evidence in physics comes down to relative positions of discrete objects and motion, that is, change of relative positions (see notably Bell 1987, pp. 166, 175). These axioms then are the answer to the question of what is a minimally sufficient ontology that accounts for this evidence. However, this is not positivism, because this approach does not employ the mathematical structure of physical theories to infer the ontology.

The distance relation has to satisfy the triangle inequality (that is, for any three matter points *i, j, k*, the sum of the distances between *i* and *j* and *j* and *k* is greather than or equal to the distance between *i* and *k*). This is the only metrical requirement. The distance relation does not have to satisfy Euclidean geometry, or to have three or four dimensions. All this is a matter of representation and not of ontology. In other words, the distance relation is subject only to a minimal spatiality or extension constraint. Nonetheless, it is this constraint that makes it that the objects that are individuated by this relation are matter points. By contrast, points standing in, say, a primitive thinking relation would be Cartesian minds, etc. Consequently, the type of relation determines which type of objects are the relata.

Furthermore, the distance relation is irreflexive, symmetric and connex (meaning that all matter points in a given configuration are related with one another). More importantly, for the distance relation to individuate the matter points, it has to satisfy the following requirement: if matter point *i* is not identical with matter point *j*, then the two sets that list all the distance relations in which these points stand with respect to all the other points in a configuration must differ in at least one such relation. It is such differences in the way in which *i* and *j* relate with the other points in the configuration that make it that *i* and *j* are different points. This requirement entails that the matter points are *absolutely* discernible. What is known as *weak* discernibility in the literature since Saunders (2006) is not sufficient for individuation, since it requires only that objects stand in an irreflexive relation, without there being anything that distinguishes one object from the other ones (see Bigaj 2015 for a recent overview of that debate). Consequently, by imposing this requirement, one avoids having to accept the plurality of matter points as a primitive fact, which would imply that the matter points are bare particulars or bare substrata. These relations also account for the impenetrability of matter without having to invoke a notion of mass: for any two matter points to overlap it would have to be the case that there is no distance between them.

However, this requirement comes at a price. It implies that any model of this ontology has to include at least three matter points that are individuated by the distance relations. Consequently, symmetrical configurations are ruled out, but also, for instance, the configuration of an isosceles triangle. Nonetheless, this is no objectionable restriction: having empirical adequacy in mind, there is no need to admit worlds with only one or two objects or *entirely* symmetrical worlds. To put the issue in other terms, axiom (1) proposes a structural individuation of objects: they are individuated by the relations in which they stand instead of intrinsic properties, or a primitive thisness (haecceity). As the literature on ontic structural realism has made clear, structures in the sense of concrete physical relations – such as distances – can individuate physical objects (see e.g. Ladyman 2007). The issue of structural individuation is independent of whether one conceives ontic structural realism in a *radical* manner, eliminating objects in the sense that they are nothing but nodes in a network of relations (Ladyman and Ross 2007, chs. 2 and 3, French 2014, chs. 5-7), or conceives it in a *moderate* manner, treating objects and relations on a par, being mutually ontologically dependent: relations require relata in which they stand, but all there is to the relata is given by the relations that obtain among them (Esfeld 2004, section 3, Esfeld and Lam 2011, McKenzie 2014). In both cases, to the extent that there are objects, they are individuated by relations.

The point at issue here comes out clearly when one considers the tension that there is in ontic structural realism between the following two claims:

(i) The symmetries that physical theories exhibit are the guide to the ontic structures.

(ii) The ontic structures individuate physical objects.

The tension consists in the fact that the higher a degree of symmetry a structure exhibits, the less it is in the position to individuate objects (Keränen 2001). This tension is general: it applies not only to spatial symmetries, but also, for instance, to quantum entanglement structures. In posing axiom (1), I propose to resolve this tension by abandoning claim (i). What we need structures in a parsimonious ontology for is to relate simple objects in such a way that the structures individuate the objects. In other words, the rationale for admitting structures in the ontology rests on claim (ii). Symmetries in physical theories then are important for representation. They are a means to achieve a description of the evolution of our universe that is both simple and informative: they entail a great improvement in simplicity with only a little loss in information about the actual configuration of matter of the universe, which is not symmetric. To put it in a nutshell: to obtain objects that are structurally individuated by the relations in which they stand, we need absolute discernibility; to obtain absolute discernibility, we have to ban symmetries in the sense of entirely symmetrical, global configurations from the ontology; doing so makes the ontology empirically adequate (since the actual configuration of matter of the universe is not symmetrical) without infringing upon the representational importance of symmetries.

By posing axiom (1), this ontology endorses not only the principle of the identity of indiscernibles, but also – Leibnizian – relationalism about space. According to Leibniz, distances make up the order of what coexists (see third letter to Newton-Clarke, § 4, in Leibniz 1890, p. 363; English translation Leibniz 2000). By adding axiom (2), this ontology follows also Leibniz on time: time derives from change. According to Leibniz, time is the order of succession (see third letter, § 4, and fourth letter, § 41 in Leibniz 1890, pp. 363, 376). Change, conceived as change in the distances among matter points that are permanent, does not presuppose any temporal notion. Nonetheless, change, thus conceived, is directed in the following sense: it goes from one particular state of the configuration of matter points consisting in certain distances among the matter points to another particular state of that configuration consisting in other distances among some matter points. Any such change may be reversible. Nevertheless, the actual change in the configuration is directed in virtue of the fact that it goes from one specific state of the configuration to another specific state of the configuration. By contrast, there is no direction in the distance relations individuating matter points as given by axiom 1, since there is no spatial direction as long as there are only distance relations, but no space into which these relations are embedded.

For change to be change in the distances that connect and individuate matter points, the matter points have to be permanent. If they were not permanent, a space-time would have to be presupposed in which matter point-events come into and go out of existence. Since the matter points are permanent, the change in the distance relations provides for the identity of the matter points in the configuration across all change. In other words, what makes *i* the same matter point through each state of the configuration is the way in which the relations it bears with respect to all the other matter points change. An appropriate manner to represent this identity therefore consists in depicting the matter points as moving on continuous trajectories.

However, why is it not a more parsimonious ontology to merge the two axioms into one by replacing the distance relations with basic spatio-temporal relations? As mentioned above, the distance relation postulated in axiom (1) implements only a minimal spatiality constraint. Going for basic spatio-temporal relations, by contrast, obliges one to admit much more than that as primitive: there then are matter point-events forming continuous worldlines, with the points on each worldline being ordered according to earlier and later as a primitive matter of fact – otherwise, the relations would not be spatio-*temporal* ones. Again, such relations can individuate worldlines, and they do not have to satisfy Euclidean geometry, or to have four dimensions; all this is a matter of representation. Nonetheless, one cannot do without endorsing a primitive temporal, metrical requirement in this ontology, even if one casts it in relationalist terms instead of endorsing an absolute space-time: well-defined spatio-temporal intervals between non-simultaneous point-events have to be presupposed as primitive. Hence, temporal order is not derived from change, but change is derived from the order of the points on each worldline being temporal as a primitive matter of fact.

If one puts the ontology set out in terms of the two axioms above into the framework of terms that are common in analytic metaphysics, the matter points are endurants because they persist without having temporal parts (but they do not have spatial parts either; they do not have any parts at all). Furthermore, since what exists is a spatial configuration of these matter points constituted by the distances among them, this is an ontology of presentism. However, employing these terms is misleading, since they presuppose time as a primitive. In this ontology, there is no time, but only change. What exists is a configuration of matter points individuated by distance relations that change. That change exists, but not a whole ordered stack of configurations of matter points – this is only a manner of representation of change. There only is one configuration of matter points of the universe, with the relations that individuate the elements of that configuration changing. This is the only reason why this ontology is akin to presentism. In any case, presentism, thus conceived, is the most parsimonious ontology, since only one configuration exists. To put it in a nutshell, this ontology achieves the best of two worlds: the Parmenedian world of eternal being and the Heraclitean world of change. The matter points are permanent; they do not come into being and they do not go out of being. But they are individuated by relations that change as a primitive matter of fact.

2. *Minimalist ontology and physical theory*

So far I have been concerned with simplicity in the sense of parsimony or minimalism in ontology: distance relations individuating matter points, with these relations changing, while the matter points are permanent, is the first and foremost candidate for a most parsimoniuos ontology of the natural world that is coherent and empirically adequate. However, when it comes to representing that change in a physical theory, the conceptual means provided by this ontology are in general insufficient. Using only these conceptual means, one could not do much better than just listing the change that actually occurs, but not formulate a simple law that captures that change.

The rationale for seeking for a law is simplicity in representation. In the ideal case, the law is such that given an initial configuration of matter as input, it yields a description of all the change of the configuration as output. However, in order to achieve such a law, we need more parameters than distances individuating matter points. The reason is that there is nothing about the distance relations in any given configuration of matter that provides information about the evolution of these relations. That is why further parameters – both geometrical and dynamical ones, over and above relative distances that change – have to be attributed to the configuration of matter points to obtain a dynamical law. Consequently, *simplicity in ontology and simplicity in representation tend to pull in opposite directions*. Using only the concepts that describe what there is on the simplest ontology (matter points individuated by distance relations), the description of the evolution of the configuration of matter would not be simple at all. Using the simplest description as guideline for the ontology – such as e.g. Newtonian mechanics –, the ontology would not be simple at all: it would in this case be committed to absolute space and time, to momenta, gravitational masses, forces, etc.

To put this crucial issue differently, from the epistemological perspective, in metaphysics as well as in physics, one has to start from a few basic notions taken as primitive. One can elucidate what these notions mean – as done with the notion of distances individuating matter points in the preceding section –, but one cannot trace them back to other notions. These notions, then, make up the proposal for the ontology in the sense of what there simply is. It is in principle possible to do the whole of physics with just the notions of distances individuating matter points and change of these distances, but this would be uneconomical: no simple dynamical equation capturing that change could be thus achieved. It is therefore reasonable to introduce further notions that provide such information by being formulated in terms of their functional role for the change in the configuration of matter so that the representation of change becomes more simple without losing information.

However, it is a misunderstanding to think that by introducing further notions one subscribes to ontological commitments that go beyond the ones given in terms of the basic notions. One can invoke the stance that is known as Humeanism in analytic metaphysics in order to illustrate why this is a misunderstanding. Hence, Humeanism enters here as a strategy to maintain scientific realism without building ontological commitments on the representational means that physical theories employ. In brief, if one takes the basic notions to define what is known as the Humean mosaic, one can conceive all the further notions that are needed to achieve a simple theory – both the geometrical and the dynamical ones – as being the means to obtain a representation of that mosaic that is simple as well as informative.

The way in which the change in the configuration of matter occurs exhibits certain patterns or regularities. Conceptualizing these patterns or regularities, according to what is known as the Humean best system account, the laws of nature are the theorems of the system that achieves the best balance between being simple and being informative in describing the evolution of the configuration of matter (see notably Lewis 1994, section 3, and Cohen and Callender 2009). More precisely, the proposal at hand here regards the parsimonious ontology of matter points individuated by distance relations and the change in these relations as the Humean mosaic. Hence, properties are banned from the mosaic: there are only the distance relations individuating point-objects. The geometry as well as the dynamical parameters that figure in a physical theory are treated in the same way as the laws: they come in through the role that they play in the laws, belonging to the means that are required to achieve a representation of the overall change in the distance relations that strikes the best balance between being simple and being informative about that change. This new version of Humeanism can be dubbed *Super-Humeanism*. While the standard Humean, following Lewis's thesis of Humean supervenience (e.g. Lewis 1986a, pp. ix-x), holds that there are spatial or spatio-temporal relations connecting points and natural intrinsic properties instantiated at these points, the Super-Humean maintains that there are only sparse points that then are matter points with distance relations individuating these points; but neither is there an underlying space nor are there natural intrinsic properties.[1]

Suppose, for the sake of the argument, that the laws of classical mechanics and classical electrodynamics are part of the best system. Mass, charge and other parameters figure in these laws. Both inertial and gravitational mass as well as charge are admitted in classical mechanics only because they perform a certain function as described by the laws of gravitation and electrodynamics, namely to accelerate the particles in a certain manner. In other words, they enter into classical mechanics through their nomological role in the laws.

Hence, on Super-Humeanism, parameters like mass and charge are no addition to being. The configuration of point particles and its change is all there is. Given that this change exhibits certain patterns, laws can be formulated, and given the laws, one can attribute parameters like mass and charge to the point particles. But these are not properties that the particles have *per se*, as something essential or intrinsic to them. They obtain them only through the regularities that the change in the distance relations among them exhibits (see Hall 2009, § 5.2). That is to say: it is not mass and charge qua properties belonging to individual matter points that determine their trajectories by means of the causal role that they play in the laws of classical mechanics and electrodynamics; on the contrary, the trajectories that the matter points take throughout the evolution of the universe make it that parameters such as mass and charge figure in the dynamical laws such that a value of mass and charge applies to the matter points taken individually. Consequently, the particles are not intrinsically electrons, neutrons, etc. They can be so described because they move electronwise, neutronwise so to speak (see Esfeld et al. 2017).

In other words, the distance relations among the point particles and the change in these relations make true all the true propositions about the natural world, including in particular the propositions expressing laws of nature. Hence, if the laws of classical mechanics figure in the best system, predicates such as "mass" and "charge" apply to the particles in virtue of the

---

1 Castaneda (1980, p. 106) uses the term "super-Humean world", meaning a view that does not regard energy (or forces) as something that exists in the world; but there is no rejection of absolute space or natural intrinsic properties considered in Castaneda. I'm grateful to Gordon Belot for suggesting the term "Super-Humeanism" for this view of a relationalism that rejects intrinsic properties of the spatial relata.

patterns that the particle trajectories exhibit. These predicates – as well as all the other ones appearing in the propositions that are true about the world – really apply, and the propositions really are true, there is nothing fictitious about them. But what there is – and hence what makes them true – is nothing over and above matter points individuated by distance relations and the change in these relations.

In the same vein, Huggett (2006) has shown how geometry and inertial frames in classical mechanics come in as figuring in the best system describing the change in the spatial relations among point particles. Consequently, going for relationalism in classical mechanics does not oblige one to develop a theory of classical mechanics that is an alternative to Newtonian mechanics (as notably Barbour and his collaborators have done since the 1970s; see e.g. Barbour and Bertotti 1982). It is sufficient to interpret the absolute quantities appearing in Newtonian mechanics as being the means to achieve a best system representation of the change in the relative distances among point particles. In a nutshell, a relationalist ontology for classical mechanics can go with a non-relationalist physical theory (see notably Belot 2011, pp. 60-77, for a critical assessment of the proposal of Huggett 2006). In any case, also a relationalist physical theory of classical mechanics requires more representational means than those provided by the sparse notions employed in the formulation of a parsimonious relationalist ontology in terms of the two axioms of the preceding section (e.g. Barbour's theory requires primitive facts about angles in order to be entitled to the notion of the shape of a configuration on which his relationalist dynamics relies).

A similar approach is available for general relativity. In brief, if one uses parsimony as the primary criterion for ontology and refuses to employ the mathematical structure of a physical theory to infer the ontology, as already mentioned in the previous section, relativity physics does not commit us to replacing distance relations (that implement only a minimal spatiality requirement) with spatio-temporal relations. Instead, one can regard even the curved geometry of general relativistic space-time as a means to represent the evolution of distance relations individuating matter points. In particular, although general relativity is not a theory of point particles, also in the case of purely gravitational phenomena – such as space-time singularities or gravitational waves –, all that is physically observable is the change of spatial relations among material bodies. Against this background, one can maintain that the relationship between the fundamental particle description and the effective field description (e.g. in terms of fluid dynamics) is one of coarse-graining (see Vassallo and Esfeld 2016). Generally speaking, starting from the parsimonious ontology defined in the previous section, it is an open issue whether the best system representing the evolution of the distance relations individuating matter points works with a dynamics of instantaneous particle interaction (as in Newtonian mechanics and in quantum entanglement) or a dynamics of retarded (and possibly also advanced) particle interactions that are mediated by fields (as in relativistic physics).

Nonetheless, it seems that fields constitute a serious obstacle to this research programme. It seems that from classical electrodynamics on, fields are recognized on a par with particles as the stuff out of which the world is made. However, in the first place, note that an electric field is probed by the motion of a test charge subject to it (such as the electron in the wire), the double slit experiment in quantum mechanics is made apparent by sufficiently many particles hitting on a screen, etc. Consequently, entities that are not particles – such as waves or fields – come in as figuring in the explanation of the behaviour of the particles, but they are not themselves part of the experimental evidence. More importantly, an ontological commitment to fields as mediators of particle interactions runs into both physical and philosophical trouble (see Lange 2002 for a good introduction to the debate about fields in physics and philosophy). As regards the physics, there is the problem of self-interaction: the field that a charge creates reacts back on that very charge, resulting in an infinite energy at the point of the charge; this mathematical problem motivates the search for a physical theory that works without the field variables (such as the theory of Wheeler and Feynman 1945). Furthermore, as Feynman (1966, pp. 699-700) stresses in his Nobel Lecture, fields spreads out to infinity, being defined everywhere in space-time, thus also in regions where there will never be any particles whose motion they influence. What then are the fields? Are they properties of space-time points, albeit not geometrical ones? Are they some sort of stuff filling all of space-time?

If fields are properties of space-time points, one is committed to an absolute space or space-time whose points instantiate the field properties (see Field 1985, pp. 40-42). Over and above the drawbacks that the commitment to an absolute space or space-time implies, geometrical properties are *bona fide* properties of space-time; but it is not clear to say the least how space-time points can in addition have causal properties that influence only the motion of certain particles, namely the charged ones. If one conceives fields as a stuff filling space-time, one is committed to the view of a bare substratum of matter that, moreover, admits different degrees at different points of space-time as a primitive fact. As these issues show, one runs into new problems if one treats fields as being more than bookkeeping devices that summarize the effects of diachronic relativistic particle interactions in order to allow for an efficient description of physical systems in terms of well-defined initial data.

In quantum mechanics, the wave function takes the place of the classical field parameter. It is here that the elegance of the Super-Humean treatment of the field parameter fully comes out. By contrast to the electromagnetic field, the wave function cannot be conceived as a field on three-dimensional space or four-dimensional space-time, since it does not attribute definite values to the points of that space or space-time. It is a field parameter defined on configuration space – in the last resort, due to quantum entanglement, the configuration space of the particle configuration of the universe. If one holds that this field parameter exists over and above the particle configuration, one runs into the problem of how a field on configuration space could influence the motion of particles in physical space. The Super-Humean does not have this problem.

To see this, let us cast Super-Humeanism in terms of the primitive ontology approach to quantum physics mentioned already at the beginning of section 1, with the primitive ontology being the distribution of matter in ordinary space. Bohmian mechanics is the most prominent primitive ontology approach, the primitive ontology being point particles that are characterized only by their relative positions in physical space. All other variables, including mass and charge, are situated on the level of the wave function. These particles move according to a deterministic law – the guiding equation – in which the wave function has the job to yield the particles' velocities at any time *t* give their positions at *t*. This law is linked with a probability measure – the quantum equilibrium hypothesis – from which the quantum mechanical probability calculus follows.[2]

2 See Dürr et al. (2013, in particular ch. 2) for Bohmian mechanics. See Dickson (2000), Allori et al. (2008) and Esfeld et al. (2014, 2017) for the Bohmian particles being characterized by their relative positions only.

The argument for the primitive ontology approach in general and the Bohmian formulation of quantum mechanics in particular is independent of Super-Humeanism and the considerations that speak in favour of parsimony in ontology: the argument is that this approach provides a cogent solution to the quantum measurement problem (see notably Maudlin 2010, 2015, Belot 2012). Applying Super-Humeanism to this approach, the claim then is that the primitive ontology of relative particle positions and their change is the complete ontology. The wave function is not an additional element of the ontology. It is not a physical entity that determines the motion of the particles. On the contrary, given the motion of the particles, the regularities that their motion exhibits make it that a wave function parameter figures in the best system laws capturing that motion. Miller (2014), Esfeld (2014), Callender (2015) and Bhogal and Perry (2017) have worked this stance out independently of one another. Super-Humeanism is distinct from instrumentalism about the wave function: the wave function is the central dynamical parameter, figuring in the law of motion for the particles, as well as being itself subject to an evolution according to a law (i.e. the Schrödinger equation). These laws then are linked, via the quantum equilibrium hypothesis, with the probability calculus in which the wave function is employed to calculate probabilities for measurement outcomes according to Born's rule. In brief, the first and foremost role of the wave function is nomological instead of being an instrument to calculate probabilities; but its being nomological is interpreted in terms of the best system account of laws. Consequently, if something is nomological, this does not entail that it has an ontological status.

A similar approach can be applied to quantum field theory: an ontology of a fixed number of permanent point particles that move according to a Bohmian guiding equation is in the position to yield the operator formalism of standard quantum field theory, in exactly the same way as Bohmian mechanics yields the operator formalism of textbook quantum mechanics. In brief, starting from an equilibrium state of the particle configuration in which the motion of the particles is not observable (the "vacuum"), what appears as particle creation and annihilation events is accounted for in terms of excitations of the equilibrium state (see Colin and Struyve 2007 and Deckert et al. 2016).

To stress again, note that the ontology defined by the two axioms in the preceding section has a much wider scope than what is known as the primitive ontology approach to quantum physics. Notably, it is not tied to three-dimensional space; the distance relations defining this ontology are not wedded to a particular geometry. Thus, from the perspective of this ontology, the main objection to an ontology of only a wave function in configuration space (see Albert 2015, chs. 6 and 7) is not that the wave function only ontology lacks a primitive ontology in terms of objects that are localized in three-dimensional space. From the perspective of parsimony, the main objection is the uneconomical dualism of a space defined at least by topological relations and material entities (such as a wave function field) existing on that space that are defined in terms of some intrinsic features, which hence do not come out of the relations constituting that space.

In sum, the ontology of matter points being individuated by distance relations and the change of these relations is able to cover all established physical theories from Newtonian mechanics to quantum field theory. It remains stable; what varies is the dynamical structure of physical theories, as we make progress towards finding physical theories that strike an ever better balance between being simple and being informative about the evolution of the configuration of matter. By distinguishing between simplicity in ontology and simplicity in representation, we thus obtain a scientific realism that is much more robust against the objections from theory change and underdetermination than the scientific realism that seeks to infer ontology from the mathematical structure of physical theories.

3. *A loss in explanation?*

As mentioned in section 1, the reason for employing parsimony as the primary criterion for ontology is that for any candidate entity stemming from science – or common sense, or intuitions –, we need an argument why one should endorse an ontological commitment to that entity. Its being part of what is minimally sufficient to obtain an ontology of the natural world that is coherent and empirically adequate is the best argument for an ontological commitment. That argument is not trumped by the fact that in the dynamical structure of a physical theory, much more parameters figure than those representing the entities that are admitted in a minimalist ontology. The purpose of the dynamical structure of a physical theory is simplicity in representation, not ontology. The argument for admitting (some) of these other parameters to the ontology can therefore not be the mere fact of their appearing in the dynamical structure of an established physical theory, but that by including them in the ontology, one achieves deeper explanations than those that are possible in the framework of a minimalist ontology.

The central issue in this respect is that the minimalist ontology as defined by the two axioms in section 1 has to endorse not only distances individuating matter points as primitive (axiom 1), but also all the change that occurs in the distance relations (axiom 2). It cannot provide any reason why that basic change happens as it does, although it can explain all the other phenomena in terms of change in the distance relations connecting simple point-objects. Of course, standard scientific explanation in terms of covering laws, or unification is also available to the Humean who is only committed to a Humean mosaic as given by these two axioms.[3] The point at issue here is what may be dubbed "metaphysical explanation", namely providing a reason for why the change that actually occurs in the configuration of matter of the universe happens, and not some other change. Admitting laws as further primitives to the ontology (see notably Maudlin 2007), tracing that change back to modal properties of the basic entities such as dispositions or powers with the laws representing these dispositions or powers (see notably Mumford 1998, 2004 and Bird 2007), or to modal structures that are instantiated by the configuration of the basic entities with the laws representing these structures (see notably French 2014, chs. 9 and 10) are the main candidates for additional ontological commitments that deliver such a reason.

However, in subscribing to such commitments, one does not provide an explanation of the change in the distance relations that is illuminating by contrast to accepting that change as a primitive as does the Humean. It is true that one traces that change back to modal properties of the matter points, modal structures instantiated by their configuration, or laws endorsed as primitive. But all these are *defined* in terms of the causal role that they exert for the motion of matter. The explanations hence are circular. For instance, one does not give a deeper explanation of attractive particle motion – i.e. answer the question why attraction happens in addition to subsuming it under unifying laws – in terms of mass or the gravitational force, because these are defined through the effect that they have (or can have or are the power to have) on the motion of the particles. By the same token, one does not give a deeper

3 For the debate about explanations in Humeanism, see Loewer (2012) and then Lange (2013), Marshall (2015) and Miller (2015).

explanation of quantum non-locality in terms of a modal structure of quantum entanglement, because this structure is defined in terms of correlating the possible ways in which the quantum objects that instantiate this structure can evolve. The same goes for laws admitted as primitive. All this is an instance of the scheme at which Molière pokes fun in *Le malade imaginaire*: one does not explain why people fall asleep after the consumption of opium by attributing a dormitive power to opium – although, of course, mass and charge, or quantum entanglement are sparse, fundamental properties or structures by contrast to the phenomenological properties of opium. Nonetheless, the Molière argument hits also these latter properties or structures: like the dormitive power of opium, they are defined in terms of the effects that they bring about under certain conditions – in other words, by the functional or causal role that they exercise for the evolution of the objects to which they are attributed.

The situation is similar when it comes to an ontological commitment to substantival space. For instance, Maudlin (2007, pp. 87-89) takes length of a path in absolute space as the primitive notion and derives the notion of distance of point particles from that notion as the minimal path length connecting them, claiming that he is thereby able to explain the constraints on the distance relation (such as the triangle inequality). The concern, however, is that one does not in this way provide a deeper explanation of the distance relation: in order to be able to define a minimal path length in space, one has to presuppose a structure that is rich enough to accommodate a metric – as the relationalist has to presuppose a relation that is rich enough to fulfill the triangle inequality in order to count as distance relation. If one employed a primitive notion of path that does not permit a definition of minimal length, then one could not derive the distance relation from such a notion of path.

In all these cases, the additional ontological commitment has the consequence that what is contingent on the minimalist ontology comes out as necessary on the richer ontology: the Euclidean geometry is necessary given an underlying Euclidean space, the attractive motion of the particles is necessary given masses and the gravitational force, non-local correlations are necessary given a structure of entanglement, etc. However, lifting the status of something from contingent (because accepted as primitive matter of fact) to necessary does not yield a deeper explanation. It only creates drawbacks stemming from the fact that a surplus structure is endorsed – as in the case of a substantival space that stretches out to infinity, primitive laws or modal structures that may be uninstantiated, dispositions or powers that may not be manifested or that may cancel each other out (such as gravitational attraction and electromagnetical replusion between two particles cancelling one another out in certain specific situations).

Furthermore, artificial problems are raised as to how the modal entities do the trick of making matter move in a certain manner. For instance, how can a particle make other particles across space move in a certain manner in virtue of dispositions or powers that are intrinsic to it? Invoking fields as ontological mediators of particle interaction to answer that question is of no help, as mentioned in the previous section. Moreover, how can a wave function, being a field in configuration space, make matter in physical space move in a certain manner? French (2014, p. 230) and Ladyman and Ross (2007, pp. 159-161) are prepared to concede that it is not possible to distinguish concrete physical from abstract mathematical structures; but if this were so, it would be a fatal blow to ontic structural realism as a proposal for the ontology of physics by contrast to the ontology of mathematics (see Briceno and Mumford 2016). In a nutshell, the objection is that by being committed to modal, dynamical structures existing in nature, one reifies what is the mathematical representation of the evolution of the configuration of matter to a mysterious structure behind the scene of the changing distance relations that binds the motions of the material objects together.

4. Conclusion: the merits of minimalism

The case for a minimalist ontology as set out in this paper can be summed as follows:

1. Ontological commitments require giving a reason. Since necessity is out of our cognitive reach, minimal sufficiency for a coherent and empirically adequate ontology of the natural world is a good reason. An ontology of distance relations individuating matter points and change in these relations meets this standard.
2. Such an ontology is an instance of scientific realism. It is able to cover all known physics, providing a minimal set of entities that form an ontology of the natural world that matches our well-established physical theories. Furthermore, this ontology is by far less exposed to the objections to scientific realism from underdetermination and theory change than rival proposals that take the dynamical structure of physical theories as the basis to infer the ontology.
3. Enriching the ontology does not yield additional explanatory value, but creates only drawbacks and artificial problems stemming from the surplus structure one is then committed to.

Acknowledgements: A first version of this paper was presented at the conference "New trends in the metaphysics of science" in Paris in December 2015. I'm grateful to the participants for their feedback, to Max Kistler for the invitation to submit the paper to this special issue, and to three anonymous referees for their helpful comments. The programme set out in this paper is worked out in the book *A minimalist ontology of the natural world*, co-authored by Michael Esfeld and Dirk-André Deckert, forthcoming with Routledge in autumn 2017. Apart from the many discussions with Dirk-André Deckert, the view expressed in this paper is influenced by the work with my collaborators Mario Hubert, Dustin Lazarovici, Andrea Oldofredi and Antonio Vassallo.

References

Albert, David Z. (2015): *After physics*. Cambridge (Massachusetts): Harvard University Press.

Allori, Valia, Goldstein, Sheldon, Tumulka, Roderich and Zanghì, Nino (2008): "On the common structure of Bohmian mechanics and the Ghirardi-Rimini-Weber theory". *British Journal for the Philosophy of Science* 59, pp. 353-389.

Barbour, Julian B. and Bertotti, Bruno (1982): "Mach's principle and the structure of dynamical theories". *Proceedings of the Royal Society A* 382, pp. 295-306.

Bell, John S. (1987): *Speakable and unspeakable in quantum mechanics*. Cambridge: Cambridge University Press.

Belot, Gordon (2011): *Geometric possibility*. Oxford: Oxford University Press.

Belot, Gordon (2012): "Quantum states for primitive ontologists. A case study". *European Journal for Philosophy of Science* 2, pp. 67-83.

Bhogal, Harjit and Perry, Zee R. (2017): "What the Humean should say about entanglement". *Noûs* 51, pp. 74-94.

Bigaj, Tomasz (2015): "Dissecting weak discernibility of quanta". *Studies in History and Philosophy of Modern Physics* 50, pp. 43-53.

Bird, Alexander (2007): *Nature's metaphysics: laws and properties*. Oxford: Oxford University Press.

Briceno, Sebastian and Mumford, Stephen (2016): "Relations all the way down? Against ontic structural realism". In: A. Marmodoro and D. Yates (eds): *The metaphysics of relations*. Oxford: Oxford University Press. Pp. 198-217.

Callender, Craig (2015): "One world, one beable". *Synthese* 192, pp. 3153-3177.

Castaneda, Héctor-Neri (1980): "Causes, energy and constant conjunctions". In: P. van Inwagen (ed.): *Time and cause. Essays presented to Richard Taylor*. Dordrecht: Reidel. Pp. 81-108.

Cohen, Jonathan and Callender, Craig (2009): "A better best system account of lawhood". *Philosophical Studies* 145, pp. 1-34.

Colin, Samuel and Struyve, Ward (2007): "A Dirac sea pilot-wave model for quantum field theory". *Journal of Physics A* 40, pp. 7309-7341.

Deckert, Dirk-André, Esfeld, Michael and Oldofredi, Andrea (2016): "A persistent particle ontology for QFT in terms of the Dirac sea". Forthcoming in *British Journal for the Philosophy of Science*, preprint arXiv:1608.06141[physics.hist-ph]

Dickson, Michael (2000): "Are there material objects in Bohm's theory?" *Philosophy of Science* 67, pp. 704-710.

Dürr, Detlef, Goldstein, Sheldon and Zanghì, Nino (2013): *Quantum physics without quantum philosophy*. Berlin: Springer.

Esfeld, Michael (1998): "Holism and analytic philosophy". *Mind* 107, pp. 365-380.

Esfeld, Michael (2004): "Quantum entanglement and a metaphysics of relations". *Studies in History and Philosophy of Modern Physics* 35, pp. 601-617.

Esfeld, Michael (2014): "Quantum Humeanism, or: physicalism without properties". *Philosophical Quarterly* 64, pp. 453-470.

Esfeld, Michael and Lam, Vincent (2011): "Ontic structural realism as a metaphysics of objects". In: A. and P. Bokulich (eds.): *Scientific structuralism*. Dordrecht: Springer. Pp. 143-159.

Esfeld, Michael, Lazarovici, Dustin, Hubert, Mario and Dürr, Detlef (2014): "The ontology of Bohmian mechanics". *British Journal for the Philosophy of Science* 65, pp. 773-796.

Esfeld, Michael, Lazarovici, Dustin, Lam, Vincent and Hubert, Mario (2017): "The physics and metaphysics of primitive stuff". *British Journal for the Philosophy of Science* 68, pp. 133-161.

Feynman, Richard P. (1966): "The development of the space-time view of quantum electrodynamics. Nobel Lecture, December 11, 1965". *Science* 153, pp. 699-708.

Field, Hartry H. (1985): "Can we dispense with space-time?" In: P. D. Asquith and P. Kitcher (eds.): *Proceedings of the 1984 Biennial Meeting of the Philosophy of Science Association. Volume 2*. East Lansing: Philosophy of Science Association. Pp. 33-90.

French, Steven (2014): *The structure of the world. Metaphysics and representation*. Oxford: Oxford University Press.

Hall, Ned (2009): "Humean reductionism about laws of nature". Unpublished manuscript, http://philpapers.org/rec/HALHRA

Heil, John (2012): *The universe as we find it*. Oxford: Oxford University Press.

Huggett, Nick (2006): "The regularity account of relational spacetime". *Mind* 115, pp. 41-73.

Jackson, Frank (1994): "Armchair metaphysics". In: J. O'Leary-Hawthorne and M. Michael (eds.): *Philosophy in mind*. Dordrecht: Kluwer. Pp. 23-42.

Keränen, Jukka (2001): "The identity problem for realist structuralism". *Philosophia Mathematica* 9, pp. 308-330.

Ladyman, James (2007): "On the identity and diversity of objects in a structure". *Proceedings of the Aristotelian Society. Supplementary Volume* 81, pp. 1-22.

Ladyman, James and Ross, Don (2007): *Every thing must go. Metaphysics naturalized*. Oxford: Oxford University Press.

Lange, Marc (2002): *An introduction to the philosophy of physics: locality, fields, energy and mass*. Oxford: Blackwell.

Lange, Marc (2013): “Grounding, scientific explanation, and Humean laws”. *Philosophical Studies* 164, pp. 255-261.

Leibniz, Gottfried Wilhelm (1890): *Die philosophischen Schriften von G. W. Leibniz. Band 7. Edited by C. I. Gerhardt*. Berlin: Weidmannsche Verlagsbuchhandlung.

Leibniz, Gottfried Wilhelm (2000): *G. W. Leibniz and S. Clarke: Correspondence. Edited by Roger Ariew*. Indianapolis: Hackett.

Lewis, David (1986a): *Philosophical papers. Volume 2*. Oxford: Oxford University Press.

Lewis, David (1986b): *On the plurality of worlds*. Oxford: Blackwell.

Lewis, David (1994): “Humean supervenience debugged”. *Mind* 412, pp. 473-490.

Loewer, Barry (2012): “Two accounts of laws and time”. *Philosophical Studies* 160, pp. 115-137.

Lowe, E. Jonathan (2016): “The are (probably) no relations”. In: A. Marmodoro and D. Yates (eds): *The metaphysics of relations*. Oxford: Oxford University Press. Pp. 100-112.

Marshall, Dan (2015): “Humean laws and explanation”. *Philosophical Studies* 172, pp. 3145-3165.

Maudlin, Tim (2007): *The metaphysics within physics*. Oxford: Oxford University Press.

Maudlin, Tim (2010): “Can the world be only wavefunction?”. In: S. Saunders, J. Barrett, A. Kent and D. Wallace (eds.): *Many worlds? Everett, quantum theory, and reality*. Oxford: Oxford University Press. Pp. 121-143.

Maudlin, Tim (2015): “The universal and the local in quantum theory”. *Topoi* 34, pp. 349-358.

McKenzie, Kerry (2014): “Priority and particle physics: ontic structural realism as a fundamentality thesis”. *British Journal for the Philosophy of Science* 65, pp. 353-380.

Miller, Elizabeth (2014): “Quantum entanglement, Bohmian mechanics, and Humean supervenience”. *Australasian Journal of Philosophy* 92, pp. 567-583.

Miller, Elizabeth (2015): “Humean scientific explanation”. *Philosophical Studies* 172, pp. 1311-1332.

Mumford, Stephen (1998): *Dispositions*. Oxford: Oxford University Press.

Mumford, Stephen (2004): *Laws in nature*. London: Routledge.

Pettit, Philip (1993): *The common mind. An essay on psychology, society, and politics*. Oxford: Oxford University Press.

Saunders, Simon (2006): “Are quantum particles objects?”. *Analysis* 66, pp. 52-63.

Schaffer, Jonathan (2010a): “The internal relatedness of all things”. *Mind* 119, pp. 341-376.

Schaffer, Jonathan (2010b): “Monism: the priority of the whole”. *Philosophical Review* 119, pp. 31-76.

Vassallo, Antonio and Esfeld, Michael (2016): “Leibnizian relationalism for general relativistic physics”. *Studies in History and Philosophy of Modern Physics* 55, pp. 101-107.

Wheeler, John A. and Feynman, Richard P. (1945): “Interaction with the absorber as the mechanism of radiation”. *Reviews of Modern Physics* 17, pp. 157-181.