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Do Relations Require Underlying Intrinsic Properties? A Physical Argument for a Metaphysics of Relations

1. Relations vs. intrinsic properties

According to the mainstream of metaphysical thought, the world consists of independent individual things that are embedded in a spatio-temporal framework. These things are individuals, because (a) they have a spatio-temporal location, (b) they are a subject of the predication of properties each and (c) there are some qualitative properties by means of which each of these things is distinguished from all the other ones (at least the spatial-temporal location is such a property). Qualitative properties are all and only those properties whose instantiation does not depend on the existence of any particular individual; properties such as being that individual are hence excluded. These things are independent, because their basic properties are intrinsic ones. Intrinsic are all and only those qualitative properties that a thing has irrespective of whether or not there are other contingent things; all other qualitative properties are extrinsic or relational. That is to say: Having or lacking an intrinsic property is independent of accompaniment or loneliness (see Langton and Lewis (1998) and for a refinement Lewis (2001)). The basic intrinsic properties, as well as the basic relational ones, are not disjunctive; that is to say, properties such as "being round or square" are excluded.

This metaphysics can be traced back to Aristotle at least. Aristotle assumes that there is a plurality of individual things (substances) that are characterized by intrinsic properties (forms) each.[1] A prominent contemporary formulation is David Lewis' thesis of Humean supervenience. Lewis writes:

> ... all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another. ... We have geometry: a system of external relations of spatio-temporal distance between points. Maybe points of

[1] See in particular *Categories*, chapter 5, and *Metaphysics*, book VII.

> spacetime itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short: we have an arrangement of qualities. And that is all. There is no difference without difference in the arrangement of qualities. All else supervenes on that. (1986, pp. IX-X)

Thus, there are only local qualities in the sense of intrinsic properties instantiated by space-time points or point-sized particles at space-time points. Space-time points can qualify as individual things in the above-mentioned sense. Whether everything supervenes on that distribution of basic intrinsic properties is not relevant to the present context. What is important here is the claim that, except for spatio-temporal relations, all the relations between the things at the basic level supervene on their intrinsic properties.

This paper starts with exploring a challenge to this metaphysics: If the world at the basic level consists of independent things, how can we gain knowledge of their intrinsic properties? (section 1) To counter this challenge, a metaphysics of relations without intrinsic properties on which the relations supervene is proposed. The argument for this metaphysics that is put forward here is a physical one: Our best theory of the basic level of the world, quantum theory, speaks in favour of such a metaphysics (section 2). Finally, this argument is assessed in the context of today's scientific realism (section 3).

Let us assume that the world at the basic level consists of independent things. How do we know their intrinsic properties? Consider the following problem that Frank Jackson raises:

> When physicists tell us about the properties they take to be fundamental, they tell us what these properties *do*. This is no accident. We know about what things are like essentially through the way they impinge on us and our measuring instruments. It does not follow from this that the fundamental properties of current physics, or of 'completed' physics, are causal cum relational ones. It may be that our terms for the fundamental properties pick out the properties they do via the causal relations the properties enter into, but that at least some of the properties so picked out are intrinsic. They have, as we might put it, relational names but intrinsic essences. However, it does suggest the possibility that (i) there two quite different intrinsic properties, *P* and *P**, which are exactly alike in the causal relations they enter into, (ii) sometimes one is possessed and sometimes the other, and (iii) we mistakenly think that there is just one property because the difference does not make a difference (as the point is put

> in information theory). An obvious extension of this possibility leads to the uncomfortable idea that we may know next to nothing about the intrinsic nature of the world. We know only its causal cum relational nature. (1998, pp. 23-24)

The core of this argument can be reconstructed as follows: (1) We gain empirical knowledge owing to the causal relations that obtain between physical things and our senses. (2) Knowledge thus gained may refer to intrinsic properties of physical things. (3) But the way in which that knowledge is caused imposes a constraint on its content: physical properties can be identified only through the relations in which they enter. If we explain the meaning of the statements that refer to the fundamental physical properties, it turns out that these statements describe these properties as relational. (4) Identity of relations, however, does not imply identity of intrinsic properties. (5) We therefore do not know the properties of physical things insofar as they are intrinsic. In other words, we are ignorant of the intrinsic natures of things.

This argument is not tied to a traditional empiricist account of knowledge, which can admit only an indirect realism. There may be sense impressions that are part of the causal chain that leads from physical things to empirical knowledge. But the argument under consideration does not depend on the view that sense impressions are part of the content of our beliefs or that they function at least as some sort of an epistemic intermediary between our beliefs and the things in the world to which our beliefs refer. Jackson's claim about the limits of our knowledge is not the traditional one according to which we gain knowledge only of the way in which things are represented to us, but not of what they are in themselves. Jackson's claim can be generalized so that it is independent of the theory of knowledge that one holds. If one defends what is known as direct realism, one holds that (a) causal intermediaries between the things in the world and our perceptions and beliefs do not have an epistemic function and that (b), as far as epistemic relations are concerned, our perceptions and beliefs are directly about things in the world.[2] Direct realism applies to the middle-seized objects of common sense in the first place. If direct realism is extended in such a way that it applies to our empirical knowledge as a whole, including the knowledge of fundamental physical properties, the claim of the argument sketched

2 See, for instance, Snowdon (1990) as regards perception and McDowell (1994) as regards beliefs.

above is that one has direct access only to the relations in which things stand.

The argument is not that since we gain knowledge through the way in which empirical things impinge on our senses, we know only the way in which they are related to us. The argument is one about the content of empirical predicates, namely that they reveal only relations among things. The argument applies to all relations; the relations in which things stand to us do not have any special status as far as the content of empirical knowledge is concerned. To illustrate the claim, one might say that charge, for instance, is the property that makes things attract and repulse one another, mass the property that makes them move or resist being moved in a certain way, etc.

Furthermore, it could seem that Jackson presupposes an anthropomorphic view of causation as production or generation of something. We know only what is produced, but not what the power or force that produces something is in itself. One can claim that causation in this sense does not figure in the natural sciences: the laws of nature relate states of physical systems, but they do not include notions such as production or generation.[3] Nonetheless, Jackson's argument does not depend on a particular view of causation. Moreover, it applies to all relations, whether or not they are causal. The point is that the natural sciences – the statements of laws of nature that they contain – tell us something only about the way in which things are related to each other.

The argument hence contains two claims: a claim about the causes of empirical knowledge and a claim about its content. The causal claim is uncontroversial; the claim about its content is controversial. This paper is not about this controversy. I assume that the argument of Jackson (and others), if reconstructed and generalized in the way just sketched, is right as far as the basic level of the world is concerned. This paper proposes to enquire into the metaphysical consequences of this argument. If it is true that our basic physical theories give us knowledge only of the relations in which physical things stand, the mainstream of metaphysical thought is in trouble: Metaphysics has it that there are, at the basic level of the world, independent things, which are characterized by intrinsic properties each. On epistemological reflection, however, we have to concede that we do not have access to these properties insofar as they are intrinsic. A gap between metaphysics and epistemology thus arises.

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3 See already Russell (1912).

If physics tells us only about the way in which the things at the basic level of the world are related to each other, two different metaphysical positions remain open:

(1) The things at the basic level have intrinsic properties of which we cannot gain any knowledge insofar as they are intrinsic.
(2) The relations in which they stand are all there is to the things at the basic level.

The first one is the position that Jackson – somewhat reluctantly – endorses. The idea behind this position is, as Jackson puts it, an uncomfortable one, not only because of the implication that we cannot know the basic intrinsic properties, but also because, if we cannot know the basic intrinsic properties, we can apparently not be sure that these properties are physical at all. Thus, John Foster (1982, chapter 4), makes a case for an objective idealism on this basis: physics discloses only relations; the possibility that the underlying intrinsic properties are mental instead of physical is therefore left open. The link between this position and Kant's view of things in themselves then is obvious.

The main argument for this position is that (a) relations require relata, that is, things which stand in the relations, and that (b) these things have to be something in themselves, that is, must have intrinsic properties over and above the relations in which they stand. Jackson makes use of this argument when he rejects the view "that the nature of everything is relational cum causal, which makes a mystery of what it is that stands *in* the causal relations" (1998, p. 24).

Note that this argument does not say that relations presuppose intrinsic properties of the related things as a supervenience basis. It may be that all relations – except presumably for spatio-temporal ones – supervene on intrinsic properties. However, as far as the position under consideration is concerned, it is sufficient that the related things must have some intrinsic properties or other over and above standing in the relations, independently of whether or not these intrinsic properties are a supervenience basis for the relations.[4] Assume, for the sake of argument, that something which supervenes on something else does not have a real-

[4] Compare the position that Langton (1998) attributes to Kant.

ity of its own; for when God creates the world, it is sufficient that He creates the supervenience basis. Against this background, the distinction just made shows that the position under consideration can grant that at least some relations have a reality of their own so to speak. The claim is only that it is not possible that all the qualitative properties of a thing are relational.

The second position may seem unintelligible; for it has to reject the mentioned argument for the first position. However, what has to be rejected is merely the second part of the argument: One can maintain that (a) relations require relata, that is, things which stand in the relations, but that (b) these things do not have any intrinsic properties over and above the relational properties, which can in principle be captured by physics.

By a "thing", I mean in this paper anything that is a subject of the predication of properties, including relational properties (relations), without being itself predicated as a property of something. I do not distinguish relations from relational properties: one can maintain that relations are properties as well in that they are predicated of things. The metaphysical claim then is that relations are identical with relational properties. Moreover, something can be a thing without being an individual thing; for something to be an individual thing (an individual), further conditions have to be met such as (a) being distinguishable from all the other things by means of the predication of some qualitative properties or (b) having a primitive thisness (haecceity).[5] If the abovementioned condition is necessary and sufficient for something to be a thing, it might seem more appropriate to use the term "entity" instead of the term "thing". However, the term "entity" is not precise enough; for properties are entities as well. By speaking of properties, I do not mean to be committed to realism about universals. For instance, one may claim that properties, including relational properties (relations), are tropes and countenance irreducibly relational tropes.

The second position can grant that things may have non-qualitative properties over and above the relational ones such as the property of being this thing, that is, a primitive thisness; but this position is not committed to admitting primitive thisness. Accepting that relations require things which stand in the relations does not commit one to the view that these things are bare particulars. It simply means taking into account

5 See Adams (1979).

that properties, including relations, are predicated of something; this does not imply that there is more to the related things than standing in the relations. There are metaphysical problems here, but there is nothing which poses a particular difficulty for the position under consideration. If one does not endorse primitive thisness, one may say that a thing is a bundle of properties (or tropes); how a thing can be a bundle of relational properties is no more – and no less – a problem than how it can be a bundle of intrinsic properties. Hence, both the view of things as bare particulars and the view of things as bundles of properties (or tropes) are compatible with the second position.

In order to show that the second position is intelligible so that it describes a possible world, let us come back to the quotation from David Lewis at the beginning of this section. Lewis admits spatio-temporal relations as something that does not supervene on intrinsic properties of the related things. Starting from spatio-temporal relations as non-supervenient relations, let us consider the curved space-time of general relativity and imagine a world in which spatio-temporal relations are the *only* relations. That is to say, all other physical things, properties, relations are reduced to or eliminated in favour of spatio-temporal relations. These relations obtain between space-time points. Whatever a space-time point may be, would it make sense to claim that, out of metaphysical necessity, a point has to have some intrinsic properties or other in order to be able to stand in spatio-temporal relations to other points? It seems not. It seems metaphysically possible that all the qualitative properties of a space-time point consist in the spatio-temporal relations in which it stands.[6] John Foster, for one, grants that if what stands in the relations were space-time points, then there would be no need for intrinsic properties (1982, p. 72), although he is a precursor to Jackson in setting out an argument to the effect that matter has intrinsic properties that are inscrutable.

To illustrate the intelligibility of this position, consider John Wheeler's original programme of geometrodynamics. Wheeler set out to show that the curved space-time to which general relativity refers is all there is. Here is a popular statement by Wheeler of his programme:

6 A similar claim can be made about numbers. But numbers, if they exist, are abstract objects.

> Is space-time only an arena within which fields and particles move about as "physical" and "foreign" entities? Or is the four-dimensional continuum all there is? Is curved empty geometry a kind of magic building material out of which everything in the physical world is made: (1) slow curvature in one region of space describes a gravitational field; (2) a rippled geometry with a different type of curvature somewhere else describes an electromagnetic field; (3) a knotted-up region of high curvature describes a concentration of charge and mass-energy that moves like a particle? Are fields and particles foreign entities immersed *in* geometry, or are they nothing *but* geometry? (1962, p. 361)

It seems that this programme does not leave anything out: all fundamental physical properties are accounted for in terms of relational properties of space-time points. This programme describes a possible world – albeit most likely not our world, since Wheeler's original geometrodynamics failed for physical reasons.[7] However, my claim is that, notwithstanding its empirical failure, referring to that programme is sufficient to demonstrate that a metaphysics of relations without intrinsic properties of the related things is intelligible.

Since the second position describes a possible world, a stalemate between this position and the first one as far as purely metaphysical arguments are concerned is the consequence: The adherent to the first position can no longer claim that, as a matter of metaphysical necessity, the related things must have some intrinsic properties or other over and above the relations in which they stand. If the related physical things reduce to space-time points, there is no such necessity. The only way that is open to the adherent to the first position is to establish a link between specific relations and intrinsic properties such that specific relations require intrinsic properties on which they supervene. One thus has to show that the relations which our physics reveals presuppose intrinsic properties as a supervenience basis, even if we are ignorant of these properties insofar as they are intrinsic. The argument for this metaphysics then becomes an empirical one, being focussed on specific physical relations that obtain in our world.

On the other hand, the adherent to the second position does not have any means at her disposal to rule out that there are some intrinsic properties or other of the related things. Her claim can only be that, since her position is intelligible, there is no argument left for maintaining that related things must of metaphysical necessity have some intrinsic

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7 See Stachel (1974).

properties or other. Her argument can only be that, applying Occam's razor, it is superfluous to include unknowable intrinsic properties in our ontology of the basic level of the world. However, in order to make a positive case for the second position, mere conceivability is not enough. One has to establish that the specific relations which our basic physical theories treat do not allow for intrinsic properties as a supervenience basis for them. Whichever of the mentioned two positions one favours, the argument for them cannot be a purely metaphysical one; it has to take into account empirical considerations, that is, the physics of our world. In the next section, I shall therefore turn to our current best physical theory of the basic level, quantum theory, and show that this theory can plausibly be received as being about relations that do not leave room for intrinsic properties on which they supervene.

2. *The physical argument for a metaphysics of relations*

Quantum theory permits that the states of quantum systems are entangled. If we take the quantum state description to tell us something about the properties of quantum systems, entanglement is to say that the quantum systems in question do not have state-dependent properties such as position, momentum (mass multiplied by velocity) or spin angular momentum in any direction each; state-dependent are all and only those properties of a physical system that can change during the existence of the system. Instead, there are only correlations between the conditional probability distributions of the state-dependent properties of the quantum systems in question. These probability distributions are completely determined only by the global state of the systems in question taken together. Quantum theory does not include any properties of each quantum system taken separately that are a supervenience basis for these correlated probability distributions. These correlations – and thus entanglement – are independent of spatio-temporal distance.

This way of receiving quantum theory commits us to realism: there really are quantum systems, and they are as quantum theory describes them, namely subject to entanglement. Furthermore, we are committed to endorsing objective probabilities, that is, probabilities which do not indicate limits of our knowledge, but which are about properties that things objectively have; however, I shall not go into the problems that the notion of objective probabilities poses in this paper. Whatever entanglement may exactly be, it is a relation among quantum systems. "Being entangled with" is a property that is predicated of at least two quantum systems; it is thus a relational property. By admitting entanglement, we are not committed to taking a particular stance on the notorious measurement problem in quantum theory: Even if one maintains that measurement leads to a dissolution of entanglement so that, as a result of measurement, quantum systems really have definite numerical values of some state-dependent properties, entanglement has to be there in the first place before it makes sense to consider the question whether or not there are processes that dissolve entanglement.

It is not necessary that the states of quantum systems are entangled. Quantum theory has the means at its disposal to describe states of physical systems that are not entangled. These are known as product states. One may wonder whether product states refer to intrinsic properties. However, quantum theory describes physical systems in such a way that entanglement is not at all exceptional, but ubiquitous. What has to be accounted for in quantum theory is not entanglement, but cases of the absence of entanglement, if there really are such cases (if not, it has to be explained why there appear to be such cases). If anything in quantum theory that is a candidate for a state which refers to intrinsic properties is somehow derived from the relations of entanglement, then this is not a problem for the claim made above, namely that quantum theory does not include any intrinsic properties that are a supervenience basis for these relations.

Nonetheless, even if the states of quantum systems are entangled, it is possible to give a description of each of the systems in question considered separately. One may therefore wonder whether this description refers to intrinsic properties. This is a description in terms of what is known as a mixed state in the sense of an improper mixture:[8] this description contains all the information that can be acquired about each of the quantum systems considered separately. But it ignores the correlations in which the entanglement consists. Consequently, this description does not take all the factors into account that are relevant to the quantum probabilities. The description in terms of mixed states is an incomplete description of quantum systems and not a description that refers to intrinsic properties. Consequently, the availability of such a description is no problem for the claim under consideration.

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8 See d'Espagnat (1971), chapter 6.3.

The point at issue is this one: Does quantum theory give a complete description of quantum systems so that there are no intrinsic properties on which the relations of entanglement supervene? Or are there additional variables that provide for such intrinsic properties and that are not taken into account by quantum theory as it stands, so-called hidden variables? The hidden variables need not be intrinsic properties themselves. What Jackson says about the properties that physics treats in general (see the quotation in the last section) may apply to them: even if there are hidden variables, all the descriptions that any physical theory can give of them may be relational. The point merely is that explaining the quantum correlations in terms of hidden variables allows for – or even requires – intrinsic properties on which these correlations supervene, whereas quantum theory as it stands does not provide for such intrinsic properties. The question thus is whether it is possible within quantum theory to admit the existence of intrinsic properties that constitute a supervenience basis for the correlations.

Albert Einstein rejects the idea of correlations among quantum systems without intrinsic properties on which these correlations supervene. The following is a statement of the reasons for his criticism of quantum theory:

> ... it appears to be essential for ... the things introduced in physics that, at a specific time, these things claim an existence independent of one another, insofar as these things 'lie in different parts of space'. Without such an assumption of the mutually independent existence (the 'being-thus') of spatially distant things, an assumption which originates in everyday thought, physical thought in the sense familiar to us would not be possible. ... For the relative independence of spatially distant things (A and B), this idea is characteristic: an external influence on A has no *immediate* effect on B; this is known as the 'principle of local action' ... [9]

What Einstein describes in the first part of this quotation is known as the principle of separability: physical things claim an existence independent of one another. This means that their basic properties are intrinsic ones. The relations among physical systems, except for spatio-temporal relations, supervene on intrinsic properties. By saying that without this assumption, physical thought in the sense familiar to us

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[9] Einstein (1948), pp. 321-322; translation adopted from Howard (1985), pp. 187-188.

would not be possible, Einstein endorses an a priori argument for separability. Over and above separability, according to Einstein, changes in the states of physical systems conform to the principle of local action: causal relations (interactions) propagate from point to neighbouring point with a finite velocity.

The most significant result of the debate on Einstein's criticism of quantum theory is the theorem of John Bell (1964). Bell starts from Einstein's principles of separability and local action. His theorem establishes that, given some background assumptions that Einstein would not call into question, these principles impose a certain limit on the type of correlations that quantum theory assumes. In any case of entanglement, however, quantum theory predicts higher correlations between the conditional probability distributions of state-dependent properties of quantum systems than Bell's theorem permits. The predictions of quantum theory are confirmed by experiments, notably experiments of the type of Aspect et al. (1982); these experiments exclude any direct interaction between the correlated quantum systems by means of forces whose propagation does not exceed the velocity of light.

The proof of Bell's theorem is based on what is known as factorizability. The idea behind factorizability is that the probability for a certain outcome of a measurement of a physical system depends only on the parameter that is measured on the system in question, given the state of the system. Thus, Bell's theorem shows that quantum theory violates factorizability. There is a minority view according to which the violation of factorizability simply is a mathematical point that is not of philosophical interest as such.[10] This view is disputed with good formal arguments.[11] According to the received view, there are philosophical lessons to be drawn from the violation of factorizability.[12] The argument of this paper presupposes that the received view is correct.

The rationale behind the principle of separability is that quantum systems have intrinsic properties on which the correlations supervene. There are such properties independently of whether or not we can know them insofar as they are intrinsic. Note that if separability is thus construed, the claim that quantum systems have intrinsic properties on which the correlations supervene is compatible with acknowledging that

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10 See in particular Fine (1982a) and (1982b).

11 See most recently Müller and Placek (2001).

12 See in particular the papers in Cushing and McMullin (1989).

quantum theory as it stands is complete in the epistemological sense that it says all that we can say about quantum systems. The question is whether quantum theory is complete in the ontological or metaphysical sense that it describes all there is about quantum systems. Against this background, Bell's theorem entitles us to put forward the following conclusion: If there were room for intrinsic properties on which the correlations supervene (even if we cannot know these properties insofar as they are intrinsic), there could not be those correlations that quantum theory predicts. Since, however, the correlations that quantum theory predicts and that are confirmed by experiment go beyond the limit that Bell's theorem sets, quantum theory does not allow for intrinsic properties that are a supervenience basis for the correlations.

Nonetheless, Bell's theorem does not rule out hidden variables that satisfy separability out of hand. What it shows is that one has to pay a high metaphysical price for hidden variables that conform to separability. Despite Bell's theorem, one can try a causal explanation of the correlations in question as an alternative to admitting quantum entanglement. One then has to claim either that (a) correlated quantum systems are directly connected by superluminal interaction[13] or that (b) there is backwards causation[14] or that (c) there is a common cause somewhere in the intersection of the past lightcones that coordinates the behaviour of the quantum systems with the parameters that will be measured on them.[15] If one is prepared to countenance hidden variables that establish a causal connection of any of these types, then there are hidden variables that provide for intrinsic properties which are a supervenience basis for the correlations. As with any metaphysical conclusions that are put forward on the basis of physical theories, there is no question of a logical implication; what is at issue is a matter of plausibility considerations. The discussion on hidden variables that satisfy separability confirms Quine's dictum in "Two Dogmas of Empiricism" that "Any statement can be held true come what may, if we make drastic enough adjustments elsewhere in the system" (in Quine (1980), p. 43).

More importantly, entanglement concerns only the state-dependent properties of quantum systems, such as position, momentum, and spin

13 See e.g. Chang and Cartwright (1983).
14 See e.g. Price (1996), chapter 9.
15 For a recent proposal for a common cause explanation see also Hofer-Szabo et al. (1999).

angular momentum in any direction. But quantum systems also have state-independent properties such as mass and charge; these are state-independent in that their value does not change during the existence of the system. One may wonder whether these are intrinsic properties in the sense that our descriptions of mass and charge refer to intrinsic properties even if these descriptions may not describe these properties as intrinsic ones. However that may be, the state-independent properties could not be a basis upon which the quantum correlations supervene. Bringing state-independent properties into focus can therefore at most show that quantum systems may have intrinsic properties that are outside the range of quantum theory and that are irrelevant to the correlations that quantum theory describes. Thus, referring to state-independent properties can at most illustrate a point that was granted at the outset: If one puts forward an argument for a metaphysics of relations on the basis of a physical theory, one cannot exclude that the physical systems in question have some intrinsic property or other. What one can seek to establish is only that the relations which the physical theory in question treats do not allow for intrinsic properties as a supervenience basis for these relations. Nonetheless, since quantum theory is our basic physical theory, it would be desirable to derive state-independent properties within the formalism of quantum theory. The idea then is to get to state-independent properties such as charge and mass on the basis of properties that are relational in the sense of being touched by the correlations of quantum entanglement.

To sum up this brief discussion, the argument for a metaphysics of relations based on quantum theory rests upon the following assumptions:

1) Quantum theory is the basic theory of the world.
2) Relations do not in general presuppose some intrinsic properties or other of the related things, even if there is no question of intrinsic properties being a supervenience basis for the relations.
3) Bell's theorem in particular makes clear that one would have to pay an implausibly high metaphysical price if one were to endorse hidden variables that make room for intrinsic properties as a supervenience basis for the quantum correlations.

A metaphysics of quantum correlations without intrinsic properties of the related quantum systems on which these correlations supervene seems to come close to what David Mermin (1998) proposes as the Ithaca interpretation of quantum mechanics, namely that quantum theory describes a world of correlations without describing intrinsic properties of the correlata.[16] Mermin then goes on to say that "the *correlata* that underlie those correlations lie beyond the descriptive powers of physical science" (1998, p. 762) and that "in our description of nature the purpose is not to disclose the real essence of the phenomena" (1998, p. 764). However, if that were what quantum mechanics is trying to tell us, there would be nothing spectacular about it: that only relations but not what the related things are in themselves is disclosed is a point that (a) applies to any physical theory and that (b) can be made on the basis of philosophical considerations alone, as has been rehearsed in the first section of this paper. The difference between Mermin's Ithaca interpretation of quantum mechanics and the argument set out in this section is that, given the above-mentioned assumptions, quantum theory – in contrast to all the other known physical theories and in contrast to what can be maintained on the basis of philosophical considerations alone – entitles us to claim that there are no unknown intrinsic properties of the related systems on which the correlations could supervene.

The argument of this section builds upon Paul Teller's claim of relational holism in quantum mechanics. Teller characterizes this position as follows:

> By *relational holism* I will mean the claim that objects which in at least some circumstances we can identify as separate individuals have *inherent relations*, that is, relations which do not supervene on the non-relational properties of the distinct individuals. ... It is sufficient for an object to be a distinct individual that it have a non-relational property. And it is quite consistent to suppose that two such distinct individuals, each having a non-relational property, should also stand in some inherent relation to each other. (1986, p. 73)

Teller thus takes quantum systems to be distinct individuals and claims that all that is peculiar about these individuals is that they bear some non-supervenient relations to each other. In contrast to Teller's proposal, the thesis of this paper is that, as far as quantum theory is concerned, there is no need for the correlated quantum systems to have intrinsic properties over and above the correlations in which they stand. Consequently, the proposal of this paper can be applied to quantum field

16 See also Rovelli (1996).

theory as well where there no longer is a question of quantum systems being individuals.[17]

Quantum mechanics describes single physical systems such as electrons, photons, neutrons, protons and the like. These are single physical systems, because, as far as quantum mechanics is concerned, there always is a definite number of them. They are subjects of the predication of properties each – and be it properties such as "is entangled with other systems". Quantum systems of the same kind whose states are entangled are indistinguishable. There are no qualitative properties whatsoever – not even relational conditional probabilities – that distinguish one such system from all the other ones. Nonetheless, one can maintain that quantum systems are individuals if one is prepared to acknowledge non-qualitative properties such as primitive thisness.[18] The proposal made in this section is compatible with such a view. But the point is that it does not commit us to more than acknowledging that, as far as quantum physics is concerned, quantum systems are those things that stand in the correlations without any intrinsic properties or anything like a primitive thisness being required.

In quantum field theory, by contrast, we can no longer regard electrons, photons and the like as single physical systems that are subjects of the predication of properties each. Instead of being single physical systems themselves, these are treated as field quanta. Field quanta can be regarded as properties of a quantum field. There are states of quantum fields that are a superposition of states with different numbers of field quanta. The quantum correlations obtain between the conditional probability distributions of the values of field operators at space-time points. One metaphysical option therefore is to admit space-time points as the things that stand in the relations of entanglement. Quantum field theory thus corroborates the view that, as far as quantum theory is concerned, there is no need for the things that stand in these relations to have intrinsic properties.

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17 Incidentally, Teller (1995) does not mention the issue of relational holism at all in his book on quantum field theory.

18 See French and Redhead (1988).

3. *A metaphysics of relations and scientific realism*

The metaphysics of relations without underlying intrinsic properties that has been proposed in the preceding section is committed to scientific realism; for the argument for this metaphysics is based upon realism with respect to quantum theory. This metaphysics may seem to come close to what is known as structural realism in the current discussion on scientific realism. Structural realism, as set out by John Worrall (1989), is motivated by two considerations: (a) to take up the 'no miracle argument' for scientific realism, that is the argument that the success of our physical theories would be a miracle if they were not tracking truth; and (b) to pay heed to the 'argument from pessimistic induction', that is the claim that since many of our past physical theories have turned out to be false, it is likely that our present physical theories will endure the same fate. According to Worrall, what is preserved in theory change is structure. Consequently, we should be realists with respect to the structure of our physical theories.[19] The structural realist does not have to be a Platonist with respect to mathematical structure. Her claim is only that the mathematical structure of a theory (or at least a part of it) refers to something in the physical world, not that mathematical structure is something that exists independently of our conception of it. The link with the position put forward in this paper is that structure refers to relations among physical things.

However, this argument for scientific realism hangs upon the structure of a physical theory being distinguished as that what is preserved in theory change from something that is not preserved. In Worrall, the contrast is between structure and nature. He writes that "the structural realist ... insists that it is a mistake to think that we can ever 'understand' the *nature* of the basic furniture of the universe" (1989, p. 122). This is the old distinction again between structure or relations that can be known and intrinsic properties of the related things that cannot be known. The argument of the present paper is directed against a metaphysics that endorses this distinction. Moreover, one can object that it is not possible to differentiate within a physical theory between a part that

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19 The relationship between this structural realism and the structuralist approach to science of Joseph D. Sneed and the group around the late Wolfgang Stegmüller in Germany has as yet to be explored; for recent statements of the latter position see the papers in *Synthese* 130.1, January 2002.

describes structure and a part that describes the nature behind the structure.[20]

In contrast to Worrall, James Ladyman (1998) proposes what he calls metaphysical or ontic structural realism, namely the position that structure is what is real and that there is no need for intrinsic properties underlying structure (see also French and Ladyman forthcoming). Nonetheless, if structural realism is to be a reply to the 'argument from pessimistic induction', then if structure is what is preserved in theory change, structure has to be vindicated in contrast to something else which is not preserved. Ladyman concludes by envisaging that "structural realism amounts to the claim that theories tell us not about the *objects* and *properties* of which the world is made, but directly about *structure* and *relations*" (1998, p. 422), suggesting that there is no need to admit objects in our metaphysics.

Assume, for the sake of argument, that structure is what is preserved in theory change so that we should be realists about structure. The point of this paper then is that quantum theory – in distinction to the other physical theories and in distinction to purely philosophical considerations – provides for the argument that is needed to entitle us to go from (a) what can be interpreted realistically is only the description of structure to (b) there are no intrinsic properties underlying structure. Nonetheless, in distinction to the structural realism that French and Ladyman propose, the argument of this paper (1) accepts that relations require things that stand in the relations (although these things need not be individuals, and they do not have to have intrinsic properties) and (2) regards physical theories as referring to such things. In particular, the argument of the preceding section says nothing against quantum theory referring to quantum systems and describing the properties of these systems, albeit relational properties. By way of consequence, however, this argument as such cannot say anything in defence of scientific realism – apart from making clear that there is no reason to abandon scientific realism consequent upon the advent of quantum theory. If quantum theory is superseded by another basic physical theory, it may be that the claim that our basic physical theory speaks against intrinsic properties underlying the relations is no longer defensible, because an argument such as the sketched one from quantum entanglement would then no longer be available.

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20 See Psillos (1999), pp. 155-157.

The purpose of this paper has been to put forward an empirical argument for a metaphysics of relations that dismisses intrinsic properties of the relata which are a supervenience basis for the relations. The point of such a metaphysics is that there is no gap between epistemology and metaphysics: we can in principle know all there is, because we have no reason to believe that there is more to the things at the basic level of the world than the relations in which they stand. The argument for this position has to be an empirical one, since, as shown in the first section, purely philosophical considerations cannot yield an argument that speaks against intrinsic properties underlying the relations.

Abstract

This paper proposes a metaphysics of relations without intrinsic properties on which the relations supervene. The paper starts from the claim that physics can only reveal the way in which things are related to each other. Assuming that this claim is right, two metaphysical positions remain open: (a) There are intrinsic properties, but we cannot know them. (b) All there is to the physical things at the basic level is the relations in which they stand. The paper argues that purely philosophical considerations cannot decide between these two positions. There is, however, a physical argument for the second position available: Our current basic physical theory, quantum theory, supports a metaphysics of relations by speaking against intrinsic properties on which the relations in question supervene.

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