

The reality of relations

THE REALITY OF RELATIONS

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Abstract: Discussing the contemporary debate about the metaphysics of relations and structural realism, I analyse the philosophical significance of relational quantum mechanics (RQM). Relativising properties of objects (or systems) to other objects (or systems), RQM affirms that reality is inherently relational. My claim is that RQM can be seen as an instantiation of the ontology of ontic structural realism, for which relations are prior to objects, since it provides good reasons for the argument from the primacy of relation. In order to provide some evidence, RQM is interpreted focusing on its metametaphysics, in particular in relation to the very concept of relation, and to the meaning such concept assumes in the dispute between realism and antirealism.

KEYWORDS: Metaphysics of relation; structural realism; realism/antirealism debate; relational quantum mechanics; Carlo Rovelli.

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*This way of thinking the world has certainly heavy philosophical implications.
The claim of the relational interpretations
is that it is nature itself that is forcing us to this way of thinking.
If we want to understand nature,
our task is not to frame nature into our philosophical prejudices,
but rather to learn how to adjust our philosophical prejudices
to what we learn from nature.*
Carlo Rovelli e Federico Laudisa

1. INTRODUCTION

In the history of Western philosophy, several philosophers have argued for the ontological status of relations, whilst others have criticised the notion of "thing", from Heraclitus to the contemporary metaphysics of relations, passing through Nietzsche (critique of the thing-in-itself), Whitehead (process-relational philosophy), Heidegger (the *mit-sein*), Nancy (*l'être avec*), Putnam (there are no individuals except in a relative sense), just to name a few from different traditions. In the meantime, the systems theory has claimed that «what we call a part is merely a pattern in an inseparable web of relationships. Therefore, the shift of perspective from the parts to the whole can also be seen as a shift from objects to relationships»¹. As the referenced authors have underlined, this approach is recognisable in many fields, not only in the natural sciences but in the social sciences as well, especially in relation to the French Structuralism of the sixties.

Rarely, however, has a close relation between the ontological status of relations and the criticism about the notion of objects as substances been established in philosophy, that is, by demonstrating the metaphysics of relations decomposing objects in structural terms². Structural realism is one of the approaches that has embraced this goal, specifically in its ontic dimension developed by James Ladyman, arguing for the preeminence of relations over substances, as self-subsistent individual objects, and acquiring scientific evidence from quantum mechanics³. Ontic structural realism (OSR) posits relations, and not objects, as fundamental.

The aim of this paper is to discuss relational quantum mechanics (RQM) within this framework, explaining its philosophical significance as naturalised metaphysics. By "naturalised metaphysics", I mean those philosophical models of the fundamental nature of reality based on contemporary science, specifically with current fundamental physics. My claim is that RQM may be seen as an instantiation of the ontology of structural realism, as OSR, affirming the reality of relations prior to objects. In order to provide some evidence, I will interpret RQM by focusing on its metametaphysics,⁴ in particular, in relation to the concept of relation and to the meaning this

¹ F. Capra - P. L. Luisi, *The Systems View of Life*, Cambridge University Press, Cambridge 2014, p. 80.

² See J. Stachel, *Structure, individuality and quantum gravity*, in D. Rickles, S. French, J. T. Saatsi (eds.), *Structural Foundations of Quantum Gravity*, Clarendon Press, Oxford 2006, pp. 53-82, for a useful categorisation of different types of metaphysics of relations. In particular, for our topic, I would underline the importance of the first and third types, focusing respectively on relations without relata and on the priority of relations over relata.

³ J. Ladyman, *Structural Realism*, in E. N. Zalta (ed.), *Stanford Encyclopedia of Philosophy*, 2014, <http://plato.stanford.edu/entries/structural-realism/> Cited 1 March 2017.

⁴ I am not the first to aim for this goal, see: M. Bitbol, *Physical Relations or Functional Relations? A non-metaphysical construal of Rovelli's Relational Quantum Mechanics*, in «Philosophy of Science Archive» (2007), <http://philsci-archive.pitt.edu/3506/> Cited 1 March 2017; M. Brown, *Relational Quantum Mechanics and the Determinacy Problem*, in «British Journal for the Philosophy of Science» 60/4 (2009), pp. 679-695; M. Dorato, *Rovelli's Relational Quantum*

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concept assumes in the dispute between realism and antirealism. My goal is to understand its significance for the philosophical debate in metaphysics rather than discussing its consistency. However, in doing so, I will derive a positive outcome for OSR as well, providing a clear point of reference for its argument from the primacy of relations. Since structural realism derives its argument from quantum mechanism, a relational account in quantum mechanics is helpful for it.

In order to point out the significance of RQM for the contemporary debate about the metaphysics of relations – and to properly understand what "relation" may mean here – I will introduce some philosophical notions that are extrinsic to the theory but that possess a strong explanatory power for the metaphysics implicitly embedded in the model. In Section 2, I will sketch some of the core traits of the theory, defending its realistic stance. Comparison of RQM with the elements characterising antirealism in Sections 3 and 4 is done to clearly determine its realist philosophical configuration, which is commendable within the framework of structural realism. Then, in Section 5, I will deeply analyse the notion of relation, the central concept of the theory, claiming that we need to argue for its ontic valence; and I will reply to some objections to my thesis about RQM as OSR.

2. THE PHILOSOPHICAL CONFIGURATION OF RQM

RQM is a relational theory of quantum mechanics developed by the physicist Rovelli⁵. It asserts the nonexistence of a perspective-independent description of the universe, stressing the relational nature of quantum systems, criticising the instrument-independent state of a system or observer-independent values of physical quantities.

There are several formulations of quantum mechanics that attempt to build an image consistent with the data provided by the discoveries of scientists like Planck, Einstein, Bohr, Heisenberg and Dirac. I decided to focus on Rovelli's RQM because it is very challenging for the contemporary debates in the metaphysics of relations and realism.⁶ It is easy to see how this approach is related to the issue of realism – here, intended in a broad sense and not only as scientific realism – which represents a much-debated present topic after a period characterised by the prevalence of antirealism, especially in Continental philosophy. In fact, realist approaches argue – notwithstanding the differences among the various perspectives – that there are building blocks of the world, and that these are what they are independent of our conceptualisation. If we address RQM from the point of view of realism, we will find that relations are the building blocks of reality and that they are information. According to RQM, information is observer-independent.

Emphasising the relationship between measurement and observed, RQM questions the relationship between epistemology and ontology in the foundation of a naturalised metaphysics. In fact, RQM proposes an ontology that relativises properties or states of objects (or systems) to other objects (or systems). Since different observers give different descriptions of the state of the same system, the notion of state is observer-dependent. Consequently, RQM argues against the notion of "object" as an "entity" that possesses intrinsic properties, relativising properties or states of objects

Mechanics, Anti-Monism, and Quantum Becoming, in A. Marmodoro - D. Yates (eds.), *The metaphysics of relations*, Oxford University Press, Oxford 2016, pp. 235-261; B. van Fraassen, *Rovelli's World*, «Foundations of Physics» 40/4 (2010), pp. 390-417.

⁵ C. Rovelli, *Relational quantum mechanics*, «International Journal of Theoretical Physics» 66 (1996), pp. 1637-1678.

⁶ There are other relational approaches besides Rovelli's theory, as Gyula Bene's "Quantum reference systems" and Simon Kochen's "Sigma algebra of interactive properties", or interpretations close to them, for example modal interpretations. The starting point of relational theories can be traced back to Everett's relative-state interpretation. See: G. Bene, *Quantum reference systems: a new framework for quantum mechanics*, «Physica» A242 (1997), pp. 529-560; S. Kochen, *The interpretation of quantum mechanics*, «Princeton University Preprint» (1979); H. Everett, *Relative State' Formulation of Quantum Mechanics*, «Reviews of Modern Physics» 29 (1957), pp. 454-462.

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(or systems) to other objects (or systems).

The notion of an absolute observer-independent state of a system is replaced by the notion of information about a system, exchanged via physical interactions. Relations are modalities of processes, structures through which the systems interact and communicate. The structure of reality is not made of connections among objects, but of interrelated relations. Rovelli, referring to the American philosopher Nelson Goodman, argues that quantum mechanics describes those events that are interactions between processes. By "processes", Rovelli means those transitions from an interaction to another⁷ that constitute reality as a series of events, and not of objects.

Since RQM understands correlations as information, the dynamic nature of the processes is strictly connected with the second postulate of quantum mechanics – as reconstructed by Rovelli⁸ for which it is always possible to acquire new information about a system – about the unlimited information. From a philosophical perspective, this postulate underlines the procedural nature of knowledge and, in the meantime, embraces the empiricist account for which new and "a posteriori" discoveries should always challenge prior knowledge.⁹ Nevertheless, taking into account the first postulate, for which there is a maximum amount of relevant information that can be extracted from a system, we can grasp the idea that this process is discrete, since there is a limited amount of information. These two postulates do not contradict each other, as it may seem, since they claim that there is a fixed amount of relevant procedurally-acquired information. Thanks to the first postulate, we can give a complete, discrete and coherent description of a system; thanks to the second, the opportunity to modify it, gaining an epistemic success.¹⁰

Van Fraassen¹¹ has understood RQM within the framework of informational structural realism¹². In fact, Rovelli has explicitly argued for a reformulation of quantum mechanics in terms of information theory¹³, claiming that RQM describes only the information that systems have about each other. Van Fraassen has pointed out that RQM «offers a program to derive the theory's formalism from a set of simple postulates pertaining to information processing»¹⁴. In the relationship between system X and system Y , X acquires information from Y . In this specific sense, the states are "observer's information". Therefore, the wave function describes the information that the observer has on the system.

Van Fraassen's interpretation makes RQM more compatible, as shown in Section 3, with epistemic structural realism (ESR), instead of OSR as I suggest. Unless ESR may seem more

⁷ «Spatial and temporal specifications make sense only on the boundary of a process, in the context of an interaction. In other words, space and time themselves are reduced to quantum entities like the position of a quantum particle, which is determined only at interaction time, otherwise is fluctuating», C. Rovelli (ed.), *General Relativity. The Most Beautiful of Theories. Applications and Trends after 100 years*, Berlin/Munich/Boston, De Gruyter 2015, p. 234.

⁸ One of the aims of RQM is, in fact, to reconstruct the formalism of quantum mechanics without the notion of state of system. See: C. Rovelli, *Relational quantum mechanics*, cit..

⁹ «Quantum mechanics is the theoretical formalization of the experimental discovery that the descriptions that different observers give of the same ensemble of events are not universal», C. Rovelli, *Halfway Through the Woods: Contemporary Research on Space and Time*, in J. Earman - J. D. Norton (eds.), *The Cosmos of Science: Essays of Exploration*, University of Pittsburgh Press, Pittsburgh 1996, pp. 180-223, p. 206.

¹⁰ RQM posits a third postulate too, the one about the superposition principle in terms of information theory, i.e., the set of questions. I do not consider it here because it does not have anything to do with my argument.

¹¹ B. van Fraassen, *Rovelli's World*, cit.

¹² L. Floridi, *Information. A Very Short Introduction*, Oxford University Press, Oxford 2010.

¹³ Rovelli refers to the technical sense of information-theory in C. E. Shannon, *The mathematical theory of communication*, University of Illinois Press, Chicago 1949, for which the amount of information is the number of the elements of a set of alternatives out of which a configuration is chosen.

¹⁴ B. van Fraassen, *Rovelli's World*, cit., p. 390.

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reasonable for depicting RQM, specifically for its observer-dependent characterisation, I would stress the ontological valence of RQM and, thus, explain why relations as information should be understood as the building blocks of the universe and frame it within OSR.

My claim is that RQM is a realistic theory that assumes the notion of relation as primitive¹⁵; or more specifically, the physical interaction between systems and instruments as primitive. As I will explain in Section 5, OSR will posit structures as primitives, from which objects will emerge as relational "nodes"¹⁶, or intersections of the relevant relations¹⁷. Those nodes emerge from the web of relations, not the opposite, as for the standard view about relations as relata linkings, and their identity will derive by their function in the structure.

Dorato has specifically criticised RQM on this point, arguing that a theory that refers to a primitive notion deals with explanatory poverty and that it asks us «to accept it as a brute metaphysical fact about the world»¹⁸. However, to be an ontological primitive indicates an axiomatic – rather than unprovable – concept, in this case. In my opinion, moreover, OSR could provide to RQM the justification for understanding structures not only as representational tools but also in its constitutive role as well. Thus, my method consists in comparing RQM with the elements characterising antirealism in order to determine more clearly its realist philosophical configuration, which is compatible with OSR as I claimed.

3. DOES RQM DEAL WITH RELATIVISM?

RQM may seem to be a relativist theory. In fact, RQM theorises the impossibility of an absolute image of reality (no absolute states, no intrinsic properties¹⁹) in the name of the net that emerges from the relations among systems. What appears to the observer A can be different from what appears to the observer B²⁰. Thus, RQM seems to be consistent with the definition of "relativism" provided by the SEP:

«[...] "relativism" covers views which maintain that – at a high level of abstraction – at least some class of things have the properties they have (e.g., beautiful, morally good, epistemically justified) not *simpliciter*, but only relative to a given framework of assessment (e.g., local cultural norms, individual standards), and correspondingly, that the truth of claims attributing these properties holds only once the relevant framework of assessment is specified or supplied. Relativists characteristically insist, furthermore, that if something is only *relatively* so, then there can be no framework-independent vantage point from which the matter of

¹⁵ Recognising structures as primitives, Mertz has provided an ontology of structure with the aim of explaining how it is possible to conceive of relations without assuming prior relata. See: D. W. Mertz, *An Instance Ontology for Structures: Their Definition, Identity, and Indiscernibility*, «Metaphysica» 4 (2003), pp. 127–64.

¹⁶ S. French, *Structure as a Weapon of the Realist*, «Proceedings of the Aristotelian Society» 106 (2006), pp.167–185, p. 173.

¹⁷ French has developed his account through the notion of powers and, thus, understanding the relevant relations as causation. I cannot develop this topic here, but I would mention that Laudisa has envisaged developing RQM in this way too. This is meaningful because it makes clear another affinity between RQM and OSR. See: F. Laudisa, *La causalità in fisica*, in V. Allori, M. Dorato, F. Laudisa, N. Zanghì (eds.), *La natura delle cose. Introduzione ai fondamenti e alla filosofia della fisica*, Carocci, Roma 2005, pp. 395-428.

¹⁸ M. Dorato, *Rovelli's Relational Quantum Mechanics, Anti-Monism, and Quantum Becoming*, cit., p. 245.

¹⁹ «The notion rejected here is the notion of absolute, ore observer-independent, state of a system; equivalently, the notion of state-independent values of physical quantities», C. Rovelli, *Relational quantum mechanics*, cit.

²⁰ The observer should be intended as the system, in Galilean terms, from which it is possible to deduce information concerning the event x. Brown has called it "metasystem", i.e., another physical system capable of interacting with the system in such a way as to gain information about the property in question. See: M. Brown, *Relational Quantum Mechanics and the Determinacy Problem*, cit.

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whether the thing in question is so can be established».²¹

The Relativistic Schema says that Y is relative to X and thus there are not absolutes. Until this point, RQM seems consistent with this definition. Nevertheless, it is exactly through the consequences that it draws from such definitions that the incompatibility with RQM appears clear. In particular, the value-indifference and the impossibility of formulating theories, or expressing true judgments about the nature of the things, do not belong to RQM which, on the contrary, aims at a complete description of reality²².

RQM is not a relativistic theory, but a relational one, that is, relationism. If relativism indicates the inescapable relationship that determines the knowledge of reality, consisting in the duality between the observer and the observed; relationism is rather characterised by an objectivist emphasis, indicating the relational structure that constitutes two or more realities that do not exist independently. Thus, relationism is a philosophical position, affirming that relations exist as ontological primitives. In the history of Western philosophy, the name "relationism" has been referred to Leibniz's conception of space and time – a conception opposed to Newton's substantivism.²³ The Principle of Identity of Indiscernibles, a cornerstone of Leibniz's philosophy, ensures the individuality of objects, understood as "bundles" of properties; as Steven French and Décio Krause have pointed out, this definition of an object has relevant implications for all theories that place mathematical structures at the roots of reality²⁴. Nevertheless, the relationism of RQM is different from the one of Leibniz, since it claims that the space and time in which the relations will manifest themselves are indeterminate, furthering Heisenberg's insight. And so for OSR, as we will see in Section 5.

4. DOES RQM DEAL WITH ANTIREALISM?

«The declared objective of scientific research is not to provide some correct predictions, but to 'understand' how the world works. What does this mean? It means to build and develop an image of the world, that is to say a conceptual framework for thinking about the world, effective and consistent with what we know and learn about it».²⁵

RQM implies a critique of the notion of object. The objects denied by the RQM are the objects' things which characterise naive realism; denying their existence does not imply that there is nothing or that nothing is real. The challenge is to think reality in relational terms, engendering thus a new way of understanding "objects" and of imagining forms of connection that are different from the institution of links between objects.

Frequently, although there are philosophers that have argued against it²⁶, relativism is analysed

²¹ M. Baghramian - A. Carter, *Relativism*, in E. N. Zalta (ed.), *Stanford Encyclopedia of Philosophy*, 2015. <http://plato.stanford.edu/entries/relativism/> Cited 1 March 2017.

²² Often relativism is associated with the theme of points of view, from its founder Protagoras («man is the measure of all things») to 19th century Continental philosophy, especially Foucault's perspectivism and a large part of post-Nietzschean philosophy.

²³ M. Futch, *Leibniz's Metaphysics of Time and Space*, Springer, New York 2008. Rovelli underlines the historical passage from substantivism to relationalism in the understanding of the notion of spacetime. See: C. Rovelli, *Quantum Gravity*, Cambridge University Press, Cambridge 2004, pp. 54-55.

²⁴ S. French, D. Krause, *Identity in Physics: A Formal, Historical and Philosophical Approach*, Oxford University Press, Oxford 2006, pp. 8-11.

²⁵ C. Rovelli, *Che cos'è la scienza? La rivoluzione di Anassimandro*. Mondadori, Milano 2011, pp. 122-123, my translation.

²⁶ C. Rovane, *La separazione del relativismo dall'antirealismo*, in M. De Caro - M. Ferraris (eds.), *Bentornata realtà. II*

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together with its antirealist facet. RQM partakes with antirealism the claim for which there are no framework-independent facts of certain sorts. Nevertheless, RQM denies that there is no real object that corresponds to what we perceive/think, or that nothing exists outside the mind, and, even if it existed, we would not have access to it.

The relationship between RQM and the realism/antirealism debate seems to be characterised by a certain grade of ambivalence: in some respects RQM is closer to the antirealist thesis,²⁷ saying that there are no absolute states but, as for the realism in others, stressing that what we measure as relations exists. Therefore, I think it could be fruitful to make RQM more coherent from a philosophical point of view, framing it within OSR.

Michel Bitbol has proposed to interpret RQM as a neo-Kantian theory, replacing the physical (or naturalised) properties with the functional reference frames. Bitbol therefore proposes to understand the relativity of RQM in functional and non-substantial terms²⁸. Although Bitbol's proposal is very challenging, it misses the purely ontological plane of RQM.²⁹ In fact, Bitbol criticises Rovelli for a remnant of substantialism which, on the contrary, should be emphasised, not for reestablishing the self-subsistent individual objects but for recognising the ontological status of relations.

The reason is that RQM cannot be reduced to a theory that takes the theory of knowledge as its ontology, whereas it refers to an observer-dependent pattern. RQM describes the structure of matter: the interaction between systems is a primitive notion and information is exchanged via physical interactions. The reason is that there are no intrinsic properties that can be assigned to systems independently of their information-gathering interactions. Therefore, RQM cannot be regarded within the pattern of ESR, for which what the scientific theories explain are the structures through which we know the world, but not its nature. ESR does not undertake any ontological commitment. For ESR, the nature could be constituted by individual objects prior to relational structure and, therefore, relations should represent only the ways in which the objects are known by a system. But this is not what the philosophical configuration of RQM would attain, since, in my understanding, its main goal is to demolish, from an ontological point of view, the notion of intrinsic properties of objects, replacing it with the notion of correlation as information, from an ontological point of view. «[...] the physical structure of the world is identified as this net of relationships»³⁰.

5. THINKING RELATIONS RELATIONALLY

RQM, in agreement with Mermin's analysis on the statistical features of correlation³¹, makes use of the "no go" theorems, according to which relations emerge without having to leave or get anywhere as a matter of necessity, and are not intended as lines connecting two points, thus as connections between (pre-)existing objects³². Thus, for the "Ithaca interpretation of QM", only

nuovo realismo in discussione, Einaudi, Torino 2012, pp. 65-87.

²⁷ Rovelli has highlighted the negative influence of antirealism over the development of science: «Scientific antirealism, in my opinion, is not only a shortsighted application of a classical empiricist insight; it is also a negative influence over the development of science», C. Rovelli, *Quantum Gravity*, cit., p. 309.

²⁸ M. Bitbol, *Physical Relations or Functional Relations?*, cit.

²⁹ Bitbol's interpretation may lead to the Kantian ESR, and not to OSR. About Kantian ESR, see M. Massimi, *Structural Realism: a neo-Kantian perspective*, in A. Bokulich & P. Bokulich (eds.), *Scientific Structuralism*, Springer, Dordrecht 2011, pp. 1-24.

³⁰ C. Rovelli, F. Laudisa, *Relational Quantum Mechanics*, in E. N. Zalta (Ed.), *Stanford Encyclopedia of Philosophy*, 2008, <http://plato.stanford.edu/entries/qm-relational/> Cited 1 March 2017.

³¹ D. Mermin, *What is quantum mechanics trying to tell us?*, «American Journal of Physics», 35 (1998), pp. 753-767.

³² According to Dorato, RQM differs from the Ithaca interpretation of QM as it interprets the quantum systems as endowed with a probabilistic disposition to reveal certain definite values of physical magnitudes by interacting with any kind of physical system. On the contrary, the first principle of the Ithaca interpretation of QM claims for the objective reality independent of observers and their knowledge. My position here is that RQM can attain an objective account of

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correlations are real and relata are not. It is true that for RQM, as for the Ithaca interpretation of QM, «There are no things that can enter into a relation, but it is the relation that gives rise to the notion of “things”»³³, but relations should be understood as real structures. As I claim, OSR provides a coherent philosophical frameworks³⁴ that can explain the metaphysical implications of RQM. Abandoning the dogma of the existence of absolute states, objects and properties should not be interpreted in deceptive³⁵ terms, but as the maximal expression of the relatedness of the real, intending with "relation" something other than a connection between objects: the interactions between processes as structures.

Traditionally – starting from Aristotle’s categories, which were taken up in the medieval debate about the concept of relation – relation is intended as a property of an object, that is, supervenient on the intrinsic nature of the objects related. Instead, the image of the world proposed by RQM invites us to think of reality not as starting from things, which would be then connected by relationships, but as processes that manifest "things" as the result of their intertwining. Even if RQM is not based on a clear metaphysical assumption, it provides a description of reality that poses relations as real and prior to objects. Therefore, this view requires a metaphysics able to explain how it is possible to conceive structures prior to objects, without contradictions. My claim is that this metaphysics is the one drawn by OSR.

Ladyman, Ross and French’s account of OSR aims to provide an answer to the necessity of developing an ontology of structure, that is, the mathematical content of the theory, compatible with physics³⁶. As recognised by Ladyman and Ross, the roots of this "naturalised metaphysics" can be found in the work of John Worrall³⁷, who, in turn, recognised his debts to Poincaré³⁸. For them, what exists are "real patterns" to be understood as mathematical models or modal structures. Ladyman and Ross has declared their willingness to take seriously the thesis for which the world is made of structures and relations³⁹. For the authors, this thesis is positive and it is motivated by contemporary science that asks for the abandonment of a metaphysics of self-subsistent individuals. The main argument for scientific realism – OSR is among it – is expressed by the no-miracles argument: the efficacy of contemporary science is a proof that its prediction refers to an external reality, unless we explain its success as a miracle. The authors have claimed that «structural realism is supposed to be

reality without denying the observer-dependent feature and, thus, recognising as its objects the relations themselves. See: M. Dorato, *Rovelli's Relational Quantum Mechanics, Anti-Monism, and Quantum Becoming*, cit.

³³ C. Rovelli, *La realtà non è come ci appare. La struttura elementare delle cose*, Raffaello Cortina Editore, Milano 2014, p. 118, my translation.

³⁴ This does not mean that OSR has not been an object of criticism. In fact, the alleged incoherence of OSR is a major theme in the literature, specifically through the objection that we cannot have relations without relata. For a resume of the debate see S. Briceño - S. Mumford, *Relations All the Way Down? Against Ontic Structural Realism*, in A. Marmodoro, D. Yates (eds.), *The metaphysics of relations*, Oxford University Press, Oxford 2016, pp. 198-217. For a critical examination of the thesis defended by its "founder" John Worrall, cf. S. Psillos, *Is Structural Realism the Best of Both Worlds?*, «Dialectica» 49 (1995), pp. 15-46. For one of the first reply to the criticism by the very proponents of OSR, cf. S. French - J. Ladyman, *Remodelling Structural Realism: Quantum Physics and the Metaphysics of Structure*, «Synthese» 136 (2003), pp. 31–56. See also S. French, J. Ladyman, *In Defence of Ontic Structural Realism*, in A. Bokulich & P. Bokulich (eds.), *Scientific Structuralism*, Springer, Dordrecht 2011, pp. 25-42.

³⁵ Even if Rovelli himself uses deceptive terms at times: «The world of existent things is reduced to the world of possible relations. Reality is reduced to interaction. Reality is reduced to relation», C. Rovelli, *La realtà non è come ci appare*, cit., p. 118, my translation.

³⁶ J. Ladyman, *What is Structural Realism?*, in «Studies in History and Philosophy of Science» 29 (1998), pp. 409–424.

³⁷ J. Worrall, *Structural realism: The best of both worlds?*, in «Dialectica» 43 (1989), pp. 99-124.

³⁸ J. Ladyman - D. Ross, *Every Thing Must Go: Metaphysics Naturalized*, Oxford University Press, Oxford 2007, pp. 93-95.

³⁹ *Ibi*, p. 153.

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realist enough to take account of the no-miracles argument»⁴⁰.

Ladyman and Ross argue for an ontic – not only epistemic – structuralism:

«[...] there are mind-independent modal relations between phenomena (both possible and actual), but these relations are not supervenient on the properties of unobservable objects and the external relations between them. Rather this structure is ontologically basic».⁴¹

Therefore, the identity of objects depends on the relational structure of the world. Identity is structure-relative, and something could not be the thing it is unless it is located in a field of relations. The main argument for OSR brought by Ladyman and French⁴² is that postulating substantial objects as the building blocks of reality leads to a metaphysical underdetermination in the interpretation of quantum mechanics. This means that quantum particles do not obey the Leibnizian Principle of the Identity of the Indiscernibles and, thus, they do not possess individual identities⁴³. This implies that there are no absolute discernibles. Thus, the argument says that a realist account should provide a different metaphysical approach, compatible with the discovery of quantum mechanics, and OSR is exactly supposed to attain this goal, arguing for the impossibility of individuation and positing relations as fundamental. Moreover, the argument claims that OSR is the only account able to preserve realism against the decomposition of objects highlighted by quantum mechanics, since it assumes relations as fundamentals, and not substances. Doing so, OSR appears to be a reconceptualisation of ontology pushed by the discoveries of science.

The OSR's argumentative strategy is therefore to derive the primacy of relations as structures through the criticism of the notion of substances, supported by the evidence provided by quantum mechanics about physical indiscernibles. Quantum mechanics and OSR are strongly entangled in this argument: not only OSR depends from quantum mechanics regarding the evidence, but the reasons provided by OSR enhance the explanatory power of quantum mechanics. Regarding my argument: not only OSR provides the right philosophical framework to understand the image of the world proposed by RQM, but also RQM seems to be the more compatible theory with OSR, since the two are grounded on the relationality of reality. As it has been clarified by Morganti⁴⁴, the argument from the primacy of relations is the more recent argument for OSR, and it constitutes its positive claim. For example, Muller has underlined that understanding quantum particles as relationals reinforces OSR⁴⁵. Therefore, not only RQM will benefit to be framed within OSR, but the latter as well may be supported by RQM.

⁴⁰ *Ibi*, p. 128.

⁴¹ *Ibidem*.

⁴² J. Ladyman, *What is Structural Realism?*, in «Studies in History and Philosophy of Science» 29 (1998), pp. 409–424; S. French - J. Ladyman, *Remodelling Structural Realism*, cit.

⁴³ Chakravartty has addressed the issue regarding the features of everyday objects and the "objects" of quantum mechanics. Since for OSR the underdetermination pertains to the unobservable objects of quantum mechanics only, then Chakravartty has asked why we should dismiss the notion of individuality, if it fits properly for the everyday observable objects. See A. Chakravartty, *A Metaphysics for Scientific Realism: Knowing the Unobservable*. Cambridge University Press, Cambridge 2007, pp. 70-75. Consequently, as it has been already made clear in one of his previous works dedicated to ESR and OSR the author will recognise the value of thinking reality relationally, but it will not accept to state that reality is relations only, as for OSR. See A. Chakravartty, *The Structuralist Conception of Objects*, in «Philosophy of Science» 70 (2003), pp. 867–78.

⁴⁴ M. Morganti, *Is There a Compelling Argument for Ontic Structural Realism?*, in «Philosophy of Science» 78/5 (2011), pp. 1165-1176.

⁴⁵ F. A. Muller, *Whithering Away, Weakly*, in «Synthese» 180 (2011), pp. 223–33, 231.

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Dorato⁴⁶ has claimed that RQM does not take the whole as an ultimate conceptual horizon, and thus it differs not only from systems theories, but also from monism, even in terms of "priority monism"⁴⁷. This point could be considered as an objection to my claim for which RQM should be framed in OSR, since for the structuralist the whole is prior to the parts. It is the structure what defines not only the identity, but also the existence of the "things". This question has to do with the very debated issue, also among the different structuralist approaches, of ontological dependency and synchronic conception of mereology⁴⁸. I cannot go into it here in detail but let me introduce a very specific answer regarding RQM. By way of introduction, I may say that Rovelli's theory concerning the granularity of matter is not directed at the definition of the whole but, on the contrary, to quantum particles. It asks to "think small" and not to "think big". For Ladyman⁴⁹, the principle of individuation may involve relations and not intrinsic properties. Thus, for the model of OSR proposed by Ladyman, the parts are "in virtue of" relation⁵⁰. It is the relation, as structure, which is prior, since objects are defined in virtue of their relational individuation. In the meantime, I agree with Dorato regarding the fact that the image of the reality portrayed by RQM differs from the whole of the systems theories. Relationships are not already determined, but RQM permits to predict the probability of their appearance. But this is not in contrast with the core thesis for which the things are ontological dependent on the relations. OSR, in fact, is not the same as ontological holism and thus it is, at least about the nature of the granularity of matter, not passable of this objection.

Another objection to my thesis to frame RQM within OSR may arise from the central role played by the notion of information within RQM and, therefore, asking to frame it within an epistemic account, not a metaphysical one, as I have already introduced. This objection is grounded on two core thesis of RQM: (1) that correlation has no absolute meaning, since it is the information that a third system can acquire about the coupled system-observer; (2) that the properties of the systems are to be described by an interrelated net of observations and information collected from observations. The objection moves from the idea that the metaphysical level and the epistemic one are disjointed. Nevertheless, as I have already explained discussing the two postulates in Section 2, the two planes dwell together and information should be understood as physical interaction. What the observer states is the ontology of RQM. I can concede to the objection that what RQM understands as ontology derives from a very special kind of objects – relations as information – but this does not mean that these objects are not to be framed within the ontic level as OSR well does. Thus information, being a net or correlation, should be understood as a structure that for OSR has a metaphysical value.

7. CONCLUSION

Arguably, the metaphysical implications of RQM I attempted to highlight in this paper demonstrate the extreme philosophical wealth of RQM as OSR. More work should be done, especially in fully drawing the metaphysical stance of such a relational theory. Nevertheless, I think that the thesis I introduced here may be meaningful by itself, not only to fully understand the philosophical vision of the world that derives from RQM but also to provide some evidence for this metaphysics that understood relations as the very building blocks of the reality. After having depicted the philosophical configuration of the theory in Section 2, I addressed the relativist and

⁴⁶ M. Dorato, *Rovelli's Relational Quantum Mechanics, Anti-Monism, and Quantum Becoming*, cit.

⁴⁷ J. Schaffer, *Monism: The Priority of the Whole*, in «Philosophical Review» 119/1 (2010), pp. 31-76.

⁴⁸ J. Ladyman, *The Foundations of Structuralism and the Metaphysics of Relations*, in A. Marmodoro - D. Yates (eds.), *The metaphysics of relations*, Oxford University Press, Oxford 2016, pp. 177-197.

⁴⁹ *Ibi*, p. 183.

⁵⁰ *Ibi*, p. 182.

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antirealist challenges to the theory to argue for its realistic stance. Its realism has appeared to be the one that recognises reality to relations as structures and, thus, in Section 5, I depicted RQM as OSR. Doing so, I discovered that not only RQM would benefit from this operation but also OSR as well, since RQM could provide some reasons for the argument from the primacy of relations. The efficacy of my proposal has been highlighted in the end replying to two main objections, one about ontological dependency and the other about the supposed incompatibility between ESR and OSR.