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Dissolving the Measurement Problem Is Not an Option for the Realist

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This paper critically assesses the proposal that scientific realists do not need to search for a solution of the measurement problem in quantum mechanics, but should instead dismiss the problem as ill-posed. James Ladyman and Don Ross have sought to support this proposal with arguments drawn from ontic structural realism and from a Bohr-inspired approach to quantum mechanics. I show that the first class of arguments is unsuccessful, because formulating the measurement problem does not depend on the metaphysical commitments which are undermined by ontic structural realism. The second class of arguments is problematic due to its refusal to provide an analysis of the term 'measurement". It turns out that the proposed dissolution of the measurement problem is in conflict not only with traditional forms of scientific realism but even with the rather minimal realism that Ladyman and Ross themselves defend.

1 Introduction

One of the attractions of non-realist approaches to quantum mechanics (QM) is that they offer a way to dissolve the measurement problem instead of adopting a solution for it that would either have to modify the physics (such as theories with additional variables or spontaneous collapses) or drastically inflate the empirically inaccessible content of reality (such as many-worlds interpretations). Nonetheless, many metaphysicians (and some physicists) consider the abandonment of realism too high a price to pay and therefore insist that the measurement problem calls for a (realistic) solution rather than a dissolution along non-realist lines.

Could there be a third position that somehow combines the attractions of these two (seemingly opposing) camps? In this paper, I critically assess a recent proposal for such a position, which can be found in the writings of James Ladyman and Don Ross (2007; 2013). While describing their approach to the measurement problem as "roughly the sort of account favoured by earlier versions of the Copenhagen interpretation" (2013, 134), Ladyman and Ross do not think this amounts to instrumentalism, but rather seek to defend it as part of their brand of scientific realism, which combines ontic structural realism (OSR) with what they call "rainforest realism" (2007, Chapter 4). The purpose of the present paper is to show that their Copenhagen-style dissolution of the measurement problem does not fit well with a position that presents itself as a version of scientific realism.

In order to avoid misunderstandings, let me first mention an important point of agreement between Ladyman/Ross and myself. Much of their (2013) argument is directed against the simple realism-versus-instrumentalism dichotomy (with respect to QM), which they find operative in the philosophy of David Deutsch (2011). More specifically, they argue that there is much within the formalism of QM about which one can be a realist despite not being committed to any realistic solution of the measurement problem. I largely agree with this claim, noting that one need not be an ontic structural realist to appreciate this point (cf. Cordero 2001; Saatsi forthcoming). Nor am I particularly worried about Michael Esfeld's (2013) diagnosis of OSR being only a partial realism if it does not incorporate a realist treatment of the measurement problem. What I do criticize is that the dissolution of the measurement problem proposed by Ladyman and Ross undermines some specific commitments that should be part of any position deserving to be called realism (even only a partial one).

My investigation proceeds as follows. In Section 2, I will consider how OSR might seem to undermine the traditional formulation of the measurement problem, insofar as the latter depends on viewing measurement devices as being composed of quantum particles. My contention will be that while OSR incorporates some telling arguments against traditional accounts of composition, none of them justifies viewing the measurement problem as a pseudo-problem. Section 3 will then show how Ladyman's and Ross's Bohr-inspired alternative approach to the measurement problem contradicts some widely shared realist (and, relatedly, naturalist) commitments. This by itself may not be so problematic for Ladyman and Ross, because they do not subscribe to standard realism anyway. I will therefore complete my argument in Section 4 by demonstrating that some of Ladyman's and Ross's own arguments in favor of scientific realism are in tension with their proposed dissolution of the measurement problem.

2 Composition and the measurement problem

A key step in setting up the measurement problem consists in assigning a quantum state to a measurement apparatus. In the standard example (see, e.g., Myrvold 2017, Section 4), two possible final states of the apparatus are denoted by $|``0"\rangle_A$ and $|``1"\rangle_A$, corresponding to the two basis states $|0\rangle_S$ and $|1\rangle_S$ of the measured quantum system. The measurement problem then consists in making sense of the superposed final state $a|0\rangle_S|``0"\rangle_A + b|1\rangle_S|``1"\rangle_A$, which, if a and b are both nonzero, does not seem to describe anything we observe.

Obviously, this whole construction crumbles if one refuses to assign quantum states to measurement devices. Why should the quantum formalism be the appropriate tool for describing such commonsensical objects? The usual rationale is that these objects are assumed to be composed of (a very large number of) quantum particles, and this is precisely the assumption that OSR rejects. Let us therefore look whether the arguments for this rejection may also serve to undermine the formulation of the measurement problem just given.

The hostility to the idea that material bodies are made of little things is one of the recurring themes in the work of Ladyman and Ross. Early on in their seminal (2007) book *Every Thing Must Go*, they describe how analytic metaphysicians have been misled by their hankering after a general *a priori* notion of composition, which pays little or no attention to what we have learnt about specific composition relations described within various sciences. In conclusion, they note: "We have no reason to believe that an abstract composition relation is anything other than an entrenched philosophical fetish" (21).

However, this kind of criticism can be dealt with rather quickly for our purpose, by noting that no abstract metaphysical composition relation is presupposed by the claim that measurement devices are composed of quantum systems. Instead, QM itself furnishes us with the rules of how systems combine to form larger systems, and it is those rules that tell us that the compound systems can be in superposed states just as the elementary systems can. Furthermore, insofar as the quantum formalism describes interactions between the parts of compound systems, the quantum mechanical composition relation also has the necessary dynamical character that Ladyman (2017, 156) finds missing in the traditional metaphysical accounts of composition.

But of course, the mere fact that QM allows us to describe systems composed of many particles does not justify the idea that measurement devices ought to be so described, or even that they ought to be described quantum mechanically at all. In the words of Ladyman and Ross (2007, 182), "the application of the quantum formalism to macroscopic objects is not necessarily justified, especially if those objects are importantly different from microscopic objects, as indeed they are, in not being carefully isolated from the environment".

The suggestion that a quantum description becomes inappropriate to the extent that systems fail to be isolated has some initial plausibility, as the interference effects indicating quantum behavior are indeed only observed for systems that are sufficiently well isolated from their environment. In that sense, application of the quantum formalism to macroscopic objects lacks direct empirical justification. It would, however, be hasty to infer from this lack of empirical justification a lack of scientific justification in a more general sense. To see why, we should note that the most important recent progress in the study of how the lack of isolation influences the behavior of physical systems has been through the theory of decoherence (see Bacciagaluppi 2016 for a review). By operating entirely within the formalism of QM, this theory presupposes just what Ladyman and Ross seek to prohibit: the assignment of quantum states to macroscopic objects (the environment).[1] Such assignments are therefore not just a philosopher's fancy, but are soundly rooted in scientific theorizing.

A further possible reason to reject the idea of macroscopic objects being composed

[1] As is well known, the fact that decoherence theory is just an application of standard QM also implies that decoherence by itself does not solve the measurement problem (Bacciagaluppi 2016, Section 2.1).

of quantum particles is that, according to OSR, there are no particles. As the term "particle" can have different meanings, not all of which may be relevant for our purpose, we need to look at the different anti-particle arguments advanced by OSR and evaluate for each of them whether or not it threatens the usual way of setting up the measurement problem.

The historically most important and most widely discussed issue in OSR's account of particles concerns their identity and individuality (or lack thereof; see Ladyman 2016 and references therein). This issue, however, does not seem to have much relevance for the pertinence of viewing macroscopic objects as composed of quantum systems. On the contrary, the fact that there is a metaphysical debate on the (non-)individuality of quantum particles at all precisely shows that the quantum mechanics of composite systems is to some extent insensitive to whether the components are regarded as individuals or not. It is only their cardinality that matters, and this latter is unproblematic in non-relativistic QM (I will turn to relativistic quantum theory in a minute). Another way to make the same point is to note that the formalism of quantum mechanics already incorporates the features that fueled the debate on identity and individuality (namely, the indistinguishability postulate in quantum statistics and the non-supervenience of entanglement relations), so one should not expect the results of that debate to undermine the quantum mechanical account of composition.

Neither is it relevant whether particles are regarded as elementary (or fundamental) in any strong sense. I fully agree with Ladyman (2016, 202) that we should not regard them in this way, but nothing in the usual formulation of the measurement problem depends on doing so. In fact, there is excellent empirical evidence for the occurrence of superposed states in unambiguously non-elementary quantum systems (see Arndt and Hornberger 2014 for a recent review), so the whole problem can be set up without any reference to elementary or fundamental particles.

At this point, we should attend to the fact that Ladyman and Ross are not only committed to OSR but also to rainforest realism, which furnishes a sense in which even they agree that particles do exist: they are real patterns (Ladyman 2016, 203-204). This is all the more important as the particle concept becomes increasingly problematic when we turn from non-relativistic quantum mechanics to relativistic quantum field theory. The appearance of particle creation and annihilation not only undermines the abovementioned appeal to a well-defined cardinality of particles in a composite system, but it also blurs the line between particles as persisting objects and mere excitations of quantum fields. More precisely, this latter distinction now becomes dependent on the time and energy scale at which a system is considered (Ladyman 2017, 158). The merit of rainforest realism is that it takes this dependence into account and makes room for scale-relative ontological commitments.

This implies that reference to particles is unproblematic as long as the context is appropriately specified in terms of the relevant time and energy scale. Formulations of the measurement problem implicitly do this by involving only two kinds of physical systems, namely non-relativistic quantum particles and macroscopic measurement devices. Neither of them requires consideration of quantum field theoretic effects, hence the scale at which the measurement problem is formulated is not affected by the breakdown of the particle concept in quantum field theory.

In the same context, Ladyman (2017, 156-157) mentions the renormalization group to illustrate the vast difference between the naïve metaphysical picture of composition and the intricate way in which actual condensed matter physics describes how gross matter behaves in terms of interactions between atoms, electrons, and fields. Again, the reference to scientific accounts of composition is well taken, but I do not see how it could undermine the idea that matter is composed of quantum particles. In an important sense, this latter idea provides the very motivation for applying renormalization group methods in condensed matter physics, as a tool to eliminate degrees of freedom associated with the atomic constitution of matter that are irrelevant for its macroscopic behavior. At the same time, quantum measurement devices are characterized by the fact that *some* microscopic degrees of freedom (namely the ones being measured) are *not* eliminated, but do indeed affect the device's macroscopic behavior. The renormalization group has nothing to say about these degrees of freedom and it therefore does not tell against describing the measurement device with respect to them in the way that gives rise to the measurement problem.

3 Leaving "measurement" unanalyzed?

The previous section has shown that OSR's rejection of naïve views about the constitution of matter does not justify dismissal of the measurement problem as a pseudo-problem. But Ladyman and Ross (2007, 182) also propose a more general reason for dismissal, based on their commitment to naturalism:

> From the point of view of the [Principle of Naturalistic Closure], the representation of macroscopic objects using quantum states can only be justified on the basis of its explanatory and predictive power and it has neither. . . . The predictive success of QM in this context consists in the successful application of the Born rule, and that is bought at the cost of a pragmatic splitting of the world into system and apparatus.

I have already noted above (with reference to decoherence theory) that the naturalistic credentials of assigning quantum states to macroscopic objects may be better than Ladyman and Ross suppose, so let me now focus on the positive part of their proposal. The application of the Born rule is indeed successful if we simply insist (as Niels Bohr famously did) that the apparatus needs to be described classically in the sense of not being in any superposed state. Ladyman and Ross (2013, 134) explicitly sympathize with Bohr's early version of the Copenhagen interpretation, which they view as distinct from later versions in virtue of its refusal to give any story about collapse of the wave function.

Without entering into the complex debate on the history of the Copenhagen interpretation, it is noteworthy that Ladyman and Ross (ibid.) identify "an abandonment not so much of realism as of naturalism itself" in the transition from Bohr to later versions of Copenhagen, which "*did* include a story about collapse, but interpreted it as a consequence of measurement". Against this assessment, I submit that the abandonment of naturalism (and realism) takes place when one endorses Bohr's version of Copenhagen (more precisely: Ladyman's and Ross's reading of it), not when one switches from Bohr to a later version.

Ladyman's and Ross's argument for viewing Bohr's approach as compatible with scientific realism depends on the interpretation-independent content of standard QM already mentioned in Section 1. However, as we just saw, some of that content gets its empirical character only via the successful application of the Born rule — the content is interpretation-independent precisely because any viable interpretation of QM needs to incorporate the Born rule in some way.

Now the problem with the Born rule is that it speaks about the probabilities of measurement results, while it is notoriously unclear what counts as a "measurement". This critique is well known, and it is often put in terms of awkward questions for those who (in the spirit of later Copenhagen) tie the notion of measurement to a collapse of the wave function. So for example, John S. Bell (1990, 19) famously asked whether a single-celled living creature already qualified to play the role of "measurer" or whether it takes some better qualified system (with a Ph.D.?) to make the wave function collapse. But the basic point of criticism (as Bell makes clear in the rest of his paper) does not depend on any specific view of wave function collapse, but on using such a desperately imprecise notion as "measurement" in a basic assumption of physics. This is why realistic versions of QM (such as those associated with the names of Everett, Bohm, or GRW) seek to *derive* the Born rule by giving a physical account of what it is to be a measurement. Bohr, on the other hand, denies the need for such an account, as Ladyman and Ross (2013, 134) point out approvingly.

Admittedly, any theory has to operate with some basic notions which are not amenable to further analysis, so why not simply treat "measurement" as such a notion? This works well for situations in which we all agree whether the notion applies or not. But what about ambiguous cases, for example, a device that displays a measurement outcome which is not (even indirectly) observed[2] by anyone? Bohr repeatedly insisted that human observers play no essential role in the measurement process, but how can this be justified without an analysis of "measurement"? Neither our pre-theoretical nor our scientific usage of the word "measurement" seems to settle the question whether unobserved measurements should still count as measurements.

A verificationist will denounce this as yet another pseudo-question, because such events (by definition) do not make any difference to what we observe, hence we should not suppose that there are any matters of fact concerning them. But this is hard to square with realism, understood as a stance that refuses to limit reality to what we can observe, or worse still, to what we actually *do* observe. Ladyman and Ross (2007, 309) are quite honest about how their verificationism limits the domain of what counts as real, but the

[2] A useful explication of the notion of "observation" relevant for this context is given by Ladyman and Ross (2007, 307) in terms of "informational connectedness". In the following, I have this rather wide sense of "observation" in mind when I speak of "unobserved measurements" or "unobserved data".

conflict with realism is obscured by the somewhat far-fetched example they give in that context: Most realists will readily agree that "there are no grounds for regarding the other side of [the Big Bang] as part of reality" (ibid.). By contrast, many realists will think that something has gone deeply wrong if we are discouraged from believing that there is a fact of the matter as to how our measurement devices behave when no one watches them.

Before I turn (in the next section) to the question in how far Ladyman's and Ross's own version of realism should be bothered by this tension, I should also mention that there is something anti-naturalistic about drawing such anthropocentric limits around what counts as real. A thorough discussion of Ladyman's and Ross's (2007, Section 6.3) arguments for the compatibility of naturalism and verificationism is beyond the scope of this paper. Suffice it to say that these arguments are most plausible when the verifiability criterion is understood epistemically (as a policy on what our theorizing should or should not be concerned with) rather than metaphysically (as a criterion on what does or does not belong to reality). To the extent that the latter reading is implied, a naturalist is likely to wonder why reality should care which parts of it are accessible to our observation.

4 Unobserved measurements and objective modality

That the Bohrian approach to the measurement problem entails a conflict with some widespread realistic and naturalistic intuitions may not be a decisive reason against it, especially if one has already abandoned certain commitments of standard realism, as proponents of OSR have. I will therefore now try to show that the proposed dissolution of the measurement problem conflicts not only with standard realism but also with elements of scientific realism that Ladyman and Ross themselves endorse.

A first hint of this conflict appears in the role that the notion of "data" plays within rainforest realism. As we saw in Section 2, Ladyman and Ross conceive of reality in terms of real patterns, and patterns are "relations among data" (2007, 228). In their discussion of Dennett's (1991) account of real patterns, Ladyman and Ross carefully distance themselves from the kind of instrumentalism that is at least partly invited by Dennett's writing and has preoccupied many of his commentators. In the process of doing so, they acknowledge that "there are (presumably) real patterns in lifeless parts of the universe that no actual observer will ever reach" (Ladyman and Ross 2007, 203). But such realism about patterns presupposes realism about data regardless of whether they are observed or not. It is therefore in tension with non-realism about unobserved quantum measurements.

The problem comes into sharper focus when we turn to Ladyman's and Ross's (2007, Subsection 2.3.2) critique of van Fraassen's constructive empiricism. While they largely share van Fraassen's aversion to traditional metaphysics, they defend a commitment to objective modality as a crucial element of realism against his deflationary view. One reason for this is that "theories are always modalized in the sense that they allow for a variety of different initial conditions or background assumptions rather than just the actual ones, and so describe counterfactual states of affairs" (110). A constructive empiricist might regard the claim that science gives us knowledge about non-actual states of affairs as unjustified, because all we ever experience is the actual. But this, according to Ladyman and Ross, neglects the fact that we can to some extent vary what becomes actual and still experience that our theories accurately predict what we observe. In other words, the empiricist relies on a somewhat arbitrary boundary when confining the content of our theories to a description of what actually occurs.

Insofar as this accurately describes the motivation for preferring OSR to constructive empiricism, an adherent of OSR should be equally dissatisfied with versions of QM which fail to give a non-anthropocentric account of measurement, because they involve a similar boundary between what our theories do and do not tell us. In this case, it is not the boundary between what actually occurred and what could have occurred under different initial conditions (if the Born rule is modalized in the above sense, it does give us knowledge about both of these), but the boundary between what was actually observed and what actually occurred without being observed (the Born rule being silent about the latter set of events). This second boundary is just as arbitrary as the first one, because it is largely up to us which occurrent events are observed and which ones are not.

The same point can also be made in terms of demands for explanation. In general, Ladyman and Ross share van Fraassen's s skepticism towards such demands, but here is one they explicitly accept: "That we are so often able to identify regularities in phenomena and then use them for prediction needs to be explained" (Ladyman and Ross 2007, 106). If OSR is to have any advantage over constructive empiricism, the sought-after explanation cannot simply be that there are such regularities, because that explanation would be available to the constructive empiricist as well. In order to satisfy OSR's demand, the regularities need to be invested with modal force, which enables us to answer questions about counterfactual situations. Among such questions are those about what would have happened if we had not been around to observe the phenomena in question, and an explanation would hardly be deemed satisfactory if it postulated regularities that only obtain if some observer is present. But this is precisely what the Born rule does, if it is interpreted as a modally charged law but not supplemented by a non-anthropocentric account of "measurement".

To sum up, the proposal to dissolve the measurement problem along Bohrian lines conflicts not only with some commitments of standard realism (as demonstrated in Section 3) but also with the rather minimal kind of realism that Ladyman and Ross defend against van Fraassen. Furthermore, Section 2 has shown that none of the arguments for OSR serve to undermine the view that measurement devices are composed of quantum systems in the sense relevant for formulating the measurement problem. Therefore, scientific realists (including proponents of OSR) should acknowledge that the measurement problem calls for a solution, not a mere dissolution.

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