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Wigner's friend and Relational Quantum Mechanics: A Reply to Laudisa

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Abstract
Relational Quantum Mechanics is an interpretation of quantum mechanics proposed by Carlo Rovelli. Rovelli argues that, in the same spirit as Einstein's theory of relativity, physical quantities can only have definite values relative to an observer. Relational Quantum Mechanics is hereby able to offer a principled explanation of the problem of nested measurement, also known as Wigner's friend. Since quantum states are taken to be relative states that depend on both the system and the observer, there is no inconsistency in the descriptions of the observers. Federico Laudisa has recently argued, however, that Rovelli's description of Wigner's friend is ambiguous, because it does not take into account the correlation between the observer and the quantum system. He argues that if this correlation is taken into account, the problem with Wigner's friend disappears and, therefore, a relativization of quantum states is not necessary. I will show that Laudisa's criticism is not justified. To the extent that the correlation can be accurately reflected, the problem of Wigner's friend remains. An interpretation of quantum mechanics that provides a solution to it, like Relational Quantum Mechanics, is therefore a welcome one.

Keywords Relational Quantum Mechanics · Wigner's friend · Third person problem · Measurement problem

1 Introduction

The *Wigner's friend* thought experiment formulated by Eugene Wigner [15] makes it very clear how hard it is to determine when collapse happens. The story of the experiment is as follows: Wigner is standing outside a lab in which his friend is performing a measurement on a quantum system with two possible outcomes. Since Wigner himself is outside the lab, he doesn't know which outcome his friend measures. He does know that his friend and the system will interact and that therefore

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their state spaces will be combined. Wigner will therefore describe the state of the combined system of the quantum system and his friend as a superposition between the two results. With respect to the friend, the state of the quantum system has collapsed to a definite state, but for Wigner it has not. Since we normally think that systems only have one absolute quantum state, we need to decide which of the two is the case. So, who is right in their description of the situation, Wigner or his friend?

The real Wigner [15] held that, in this scenario, we should conclude that the friend is right and Wigner is wrong. Wigner in the story lacks information about what happened in the lab, whereas the friend does not. The real Wigner [15] also argues, however, that if we would replace the friend with an inanimate measuring instrument, we would not prioritize the point of view of the instrument. In this case, Wigner's description of the situation, which is that the combined system is in a superposition, would be considered right. Wigner [15] then takes this as an argument that it is the consciousness of the friend that causes the system to collapse. The reason that we take Wigner's description to be right in the case with the measuring and wrong in the case with the friend, is that the quantum state does not collapse if it interacts with an object without a consciousness. Nowadays, we don't want to attribute such importance to consciousness and it remains an open question which observer is right.

The problem of Wigner's friend has gotten renewed attention, as it has been used to formulate no-go theorems for observer-independent facts in quantum mechanics [1, 4, 8]. These three theorems use a set-up similar to the EPR-paper [7] and introduce a nested measurement at both Alice's and Bob's measurement. They depend on a set of assumptions that are all very likely and, importantly, they assume that quantum measurements have absolute outcomes that are not relative to any other system. The theorems show that the assumptions together lead to a contradiction. Hence, one of them has to go.

The assumption that there are observer-independent facts in quantum mechanics is dropped by Rovelli's Relational Quantum Mechanics (RQM) [11, 12, 14]. In fact, its main principle is that quantum states are fundamentally relative states that depend on both the system that is being measured and the observer. The attempt to attribute absolute values to quantum systems is compared with the attempt to determine the speed of a moving object relative to an absolute frame of reference: it is impossible because there is no such absolute frame of reference [12]. If we accept that quantum states are relative, Wigner's friend is not a problem anymore: the state of the quantum system relative to Wigner is a completely different state than the state of the system relative to Wigner's friend.

When it comes to the formalization of the problem of Wigner's friend, slightly different analyses are possible. Rovelli [12] has given a description of the problem of Wigner's friend, according to which the observer in the lab describes only the quantum system. It can alternatively be argued for that the observer in the lab should describe the state of the combined system of herself *and* the quantum system. With this second analysis, one would obtain a more direct contradiction with the description of the external observer, which also concerns the state of the combined system.

Laudisa [10] has recently argued that a treatment of Wigner's friend consistent with RQM should use an analysis of the second type, whereas Rovelli has used an analysis

of the first type. Laudisa also argues that with the second analysis the problem of Wigner's friend disappears. This would make it less clear that it is necessary to relativize quantum states. In this paper I will argue that Laudisa's criticism is not correct. In Sect. 2, I will describe the Wigner's friend problem and explain the different possible analyses. In Sect. 3, I will explain Rovelli's Relational Quantum Mechanics and how it solves the problem. In Sect. 4, I will discuss Laudisa's critique of RQM's solution and argue that it is unwarranted.

2 Wigner's Friend

In this section I will go into the Wigner's friend problem. I will give a formal analysis of the story that corresponds to the one given by Rovelli [12], and is used as well by Brukner [4] and Frauchiger and Renner [8] amongst others. It will become clear how this analysis differs from the second type of analysis.

The set-up of the thought experiment of Wigner's friend is that we have a quantum system S and an observer F in a closed lab and an external observer W who cannot see what goes on inside the lab (see Fig. 1). Observer F makes a measurement on S and thereby records a definite outcome, while observer W does not have access to the measurement result. To make it more concrete, we can suppose that S is an electron passing through a Stern–Gerlach apparatus that measures if the spin of the electron is up or down.

Before the measurement, let's say at moment t_0, S will be in the following superposed state:

$$\frac{1}{\sqrt{2}}\left|up\right\rangle + \frac{1}{\sqrt{2}}\left|down\right\rangle \tag{1}$$

When F makes a measurement on S at t_1, F obtains a definitive measurement outcome: up or down. This means that the state of S changes into an eigenstate of the spin-property. Suppose that at t_1, F measures that the electron's spin is up. She will then apply the collapse postulate and describe the time evolution of S from t_0 to t_1 as

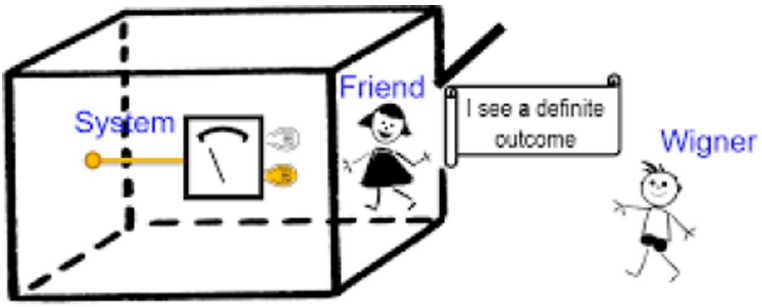

Fig. 1 Wigner's friend set-up from Brukner [3, 4]

follows, where the vector before the arrow represents the state of S at t_0 and the vector after the arrow represents the state of S at t_1:

$$\frac{1}{\sqrt{2}}\left|up\right\rangle + \frac{1}{\sqrt{2}}\left|down\right\rangle \Rightarrow \left|up\right\rangle \tag{2}$$

Now we can consider how the external observer W would describe the measurement. Observer W doesn't know if F measures up or down. However, W does know that S will start in a superposition of the spin-property and that F will measure its spin. Since F and S interact when F makes the measurement, their states spaces will be combined with the tensor product. Observer W will then describe the time evolution of the measurement as follows, where we take $|F - ready\rangle$ to represent the state of F before the measurement and $|F - up\rangle$ to represent the state of F after measuring that the electron's spin is up (and likewise for spin down):

$$\begin{aligned}\left(\frac{1}{\sqrt{2}}|up\rangle + \frac{1}{\sqrt{2}}|down\rangle\right) \otimes |F - ready\rangle \Rightarrow \frac{1}{\sqrt{2}}|up\rangle \otimes |F - up\rangle \\ + \frac{1}{\sqrt{2}}|down\rangle \otimes |F - down\rangle\end{aligned} \tag{3}$$

We see that W ends up ascribing a superposition to the combined state of S and F that we refer to as $S + F$. We thus get two different accounts of the measurement: according to F, a collapse has occurred and according to W it has not. Even though W knows that the state of S will collapse with respect to F, W cannot apply the collapse postulate because he doesn't know what state it collapses to.

This is problematic, because according to the standard interpretation collapse either absolutely happens or not. The idea is that we should apply the collapse postulate to the quantum state of a system whenever a measurement has occurred. In general, it is assumed that if the quantum system becomes correlated with some device that can store information about the quantum system, we call this a measurement. However, in the case of Wigner's friend, even though S has become correlated with F, we normally hold that W is not in a position to apply the collapse postulate to the state of S because he does not know the outcome of the measurement.

A natural thought is that since F has more information about S than W, F's account of the measurement should be prioritized. However, this position is considered less attractive in the case in which we replace the friend with an inanimate physical object. According to our modern definition of a measurement, the same conclusion should hold if the outcome is only registered by a measurement apparatus. It seems less obvious to prioritize the perspective of an inanimate object over that of the human observer. Hence, it is still an open question when collapse happens and how we should account for Wigner's friend.

On the analysis I have presented here, there is no direct logical contradiction between the state assignments made by F and W, because F assigns a state to S, and W assigns a state to $S + F$. The values that are assigned concern different quantum

systems. This means that there is no inconsistency in the quantum theory of one single observer. Brukner [4] argues for a similar understanding of the experiment:

> The fact that the friend and Wigner have different accounts of the friend's measurement process is at the heart of the discussion surrounding the Wigner-friend thought experiment. Still the difference needs not give rise to any inconsistency in practicing quantum theory, since the two descriptions belong to two different observers, who remain separated in making predictions for their respective systems. [4, p. 3]

One could argue for a different analysis of the thought experiment according to which F does not only describe the quantum system S, but the combined system $S + F$. This is also how the thought experiment was initially phrased by Wigner [15]. One then obtains a more direct contradiction, because W and F give a different description of the same system. However, it depends on the chosen interpretation of quantum theory whether it is possible to assign a quantum state to one's own system. As we will see, RQM does not allow for observers to describe their own quantum state.

I will explain why this is the case in Sect. 4, but for now it is important to see why Wigner's friend poses a problem if we use the analysis presented above. The analysis shows that observers can disagree about whether or not the quantum state has collapsed or not. Even if this is not a direct contradiction, it is an issue if we hold that collapse either absolutely happens or not. In the following section it will become clear that RQM provides a straight-forward solution to this problem.

3 Relational Quantum Mechanics

Relational Quantum Mechanics (RQM) is developed mostly by Rovelli [11, 12, 14] and, just like QBists, Rovelli argues for a relativization of quantum states. However, according to QBism, the quantum state represents the subjective degrees of belief of the observer, whereas RQM does not treat the quantum state as something that is purely epistemic. The quantum state is understood as a relative state between system and observer but the observer can be any physical system, including inanimate objects.

Rovelli [12] makes a comparison between the relativization of quantum states and Einstein's Special Relativity Theory. According to relativity theory, the speed of a moving object X is a relative physical quantity. This means that there does not exist an observer-independent fact about the speed of X. However, we do not consider the speed of X relative to some observer Y to represent the subjective belief Y has about X. The speed of X can be defined relative to any frame of reference, independently of whether there is a conscious agent present in this frame. The same goes for a quantum state according to RQM: quantum states are fundamentally relative states that exist in relation to any other physical system. Rovelli holds that these relative states are all there is, hence that quantum mechanics is a complete theory [12].

It is stressed in RQM that a measurement is simply an interaction between two physical systems. Some system (the observer) A interacts with quantum system S

and thereby obtains information about the state of *S*. The "collapse" of the state of *S* can thus be understood as an update of the information *A* has about *S*. This does not mean that collapse is something that happens in the mind of a conscious observer, because "information" in RQM is understood as a physical quality, as it is in Shannon's Information theory [13].

Shannon's definition of information is very similar to the Gibb's notion of entropy and captures the possible configurations that a system can be in with respect to some other system. If *A* and *S* do not physically interact, the state of *A* is independent of the state of *S*. Hence, knowing the state of *A* does not give us any information about the state of *S*. However, if *A* and *S* do interact (i.e. a measurement occurs), the state of *A* will become dependent on the state of *S* (and the other way around), because *A* will register the state of *S*. This means that if we know something about the state of *A*, we will get information about *S* as well. In this sense, *A* can be said to "have information about *S*".

When no measurement occurs, the system *A* can describe system *S* by using the Schrödinger equation. Rovelli and Smerlak however explain that in RQM 'physical reality is taken to be formed by the individual quantum events through which interacting systems (objects) affect one another' [14, p. 429]. These quantum events are taken only to exist when systems interact, i.e. when a measurement occurs. Hence, the outcomes of measurements are taken to be more important in RQM than the descriptions made with the Schrödinger equation [5, 6].

In RQM the wave function is understood as a book-keeping device that tracks what will happen upon the next interaction [11]. It encodes any previous interaction that *A* has had with system *S* and allows *A* to predict the state of *S* with respect to *A* in the future. It is said that RQM's interpretation of the wave function can be understood to be similar to the standard interpretation of the functional *S* in the Hamilton–Jacobi equation [9]. This functional is used as a tool to calculate the trajectory of a system in classical mechanics, but the functional itself is not taken to represent some real physical quantity. It is suggested that, analogously, the wave function in RQM can also be understood as a bookkeeping device instead of a representation of a real physical quality.

It can be questioned, however, if it is necessary for RQM that the wave function does not represent any real physical quantity. There seems to be no important motivation for this. If the goal is to account for situations like Wigner's friend, the relativization of quantum states will already achieve this. Quantum states are relative, and hence it is not a problem if there are multiple descriptions of one quantum system possible. Conversely, if the wave function would have no ontological weight, there would be no point in holding that quantum states are fundamentally relative. If the wave function would merely be a book-keeping device, it would not be an issue that two wave functions can contradict each other. These book-keeping devices would then be relative and the "real" absolute quantum states could still exist.

RQM should therefore choose between a book-keeping wave function and a relativization of quantum states, or provide an independent motivation for either of them. I suggest to keep the relativity of the quantum state as the solution to problems like Wigner's friend. This is not only because the relativization of quantum states is the core aspect of RQM, but also because it provides a more complete picture of

reality than a book-keeping wave function. If we say that the wave function does not represent a real physical quantity, the question then remains what the underlying physical quantity is that in some way gives rise to the wave function.

Regardless of which ontological status is attributed to the wave-function, the crucial import of RQM currently is that quantum states are relative states between system and observer and this is what provides a straight-forward account of the Wigner's friend story as it is formulated in Sect. 2. The problem with the experiment was that Wigner's friend has physically interacted with S and can attribute a definite state to S by applying the collapse postulate, as formulated with (2). Wigner himself has not interacted with the quantum system S yet and therefore cannot apply the collapse postulate, but will instead describe the time evolution of the state of $S + F$ as shown in (3). Hence, the measurement is described differently by the observers.

In the RQM-framework, (2) represents the time evolution of the state of S *relative* to F and (3) represents the state of $S + F$ *relative* to W. This means that the problem of Wigner's friend disappears. There is no problem with the fact that the "S relative to F" is in a definite state and that "$S + F$ relative to W" is in a superposition. As S relates to different observers, it can be described by different laws: W applies unitary time evolution and F applies the collapse postulate. The relativization of quantum states in RQM can also be understood to extend to the relativization of events, as is pointed out by Smerlak and Rovelli [14]. In this sense, the collapse of the state of S is an event that happens relatively to F, but does not happen relatively to W.

Laudisa [10] argues that Rovelli's analysis of Wigner's friend is ambiguous and that if we use an analysis of the story that is consistent with RQM, the problem with Wigner's friend will in fact disappear. In the following section I will argue that this criticism is not justified and therefore does not question the need for a relativization of quantum states.

4 Laudisa's Critique

Laudisa [10] argues that there is a problem with Rovelli's [12] description of the Wigner's friend story. He argues that the story should be analyzed differently, namely in the way I referred to at the end of Sect. 2, and that it will then become less evident that quantum states ought to be relativized. In this section I will defend RQM against this point of critique. I will argue that Rovelli's description is a correct analysis of the thought experiment and thereby restore the idea that relative states provide a much-needed solution to the problem.

Rovelli's analysis [12] of the Wigner's Friend story is the analysis that I have given in Sect. 2 and is also used by Brukner [4] and Frauchiger and Renner [8]. This is the analysis according to which Wigner's friend (F) describes only the quantum system (S). From the perspective of F, her measurement on system S can therefore be described by the time evolution in (2). Wigner (W) describes the combined system $S + F$, as is formulated in (3).

The first part of the problem that Laudisa has with this analysis is that (2) allegedly overlooks the fact that the states of F and S need to become correlated before the collapse happens [10, p. 222]. Laudisa refers to (2) as the 'E-description' and to

(3) as the 'E'-description'. The quantum system is denoted with s and the friend is denoted with O. Laudisa takes the state $|O1\rangle$ to represent the state of O when measuring that the electron is in state 1 and likewise for 2, while a and b are arbitrary coefficients. He writes:

> The E-description in the Rovelli framework as a matter of fact appears to overlook the correlation between s and O -or, better, between the states of s and the states of O- that according to quantum mechanics is assumed to take place before the collapse: namely, the evolution goes first from $a|1\rangle + b|2\rangle$ to $a|1\rangle \otimes |O1\rangle + b|2\rangle \otimes |O2\rangle$ and only after, via collapse, to $|1\rangle$. But this leads immediately to the description E'
>
> $$(a|1\rangle + b|2\rangle) \otimes |O - ready\rangle \Rightarrow a|1\rangle \otimes |O1\rangle + b|2\rangle \otimes |O2\rangle$$
>
> which is not a different sequence w.r.t. to E, but simply the same sequence under the (standard) assumption that the correlation between O and s is taken explicitly into due account. ([10, p. 222])

This E'-description that Laudisa refers to, which is the same as (3) in our analysis, however, only partly describes the measurement from F's perspective. If we want to compare F's description with W's description of the measurement, we need to consider everything that happens during the measurement. Hence, if we want to describe the measurement from F's perspective and take into account the correlation between F and S, we also need to include the moment of collapse. This would therefore not lead to E' but to a time evolution like the following:

$$\begin{aligned} &\left(\frac{1}{\sqrt{2}}|up\rangle + \frac{1}{\sqrt{2}}|down\rangle\right) \otimes |F - ready\rangle \\ &\quad \Rightarrow \frac{1}{\sqrt{2}}|up\rangle \otimes |F - up\rangle + \frac{1}{\sqrt{2}}|down\rangle \otimes |F - down\rangle \\ &\quad \Rightarrow |up\rangle \otimes |F - up\rangle \end{aligned} \tag{4}$$

Now while it is indeed true that according to ordinary quantum mechanics, a measurement like that of F on S can be described with (4), we should note that in the RQM-framework, this description is not allowed if it is given by F herself. The problem is that, according to Rovelli, F cannot describe the combined system $F + S$ [12, p. 15]. Even though it is indeed the case that F and S need to interact for F to be able to make the measurement, in the RQM-framework this interaction will not be directly represented in F's description simply because F does not include herself in the system to be described.

Rovelli argues that if an observer O performs a measurement on system S, she cannot give a dynamical description of the combined system $O + S$, because O cannot have information about herself. The context of Rovelli's explanation is that observer O has performed a measurement on S from t_0 to t_1:

> Since between times t_1 and t_0 the evolution of S is affected by its interaction with O, the description of the unitary evolution of S given by O breaks down.

> The unitary evolution does not break down for mysterious physical quantum jumps, or due to unknown effects, but simply because O is not giving a full dynamical description of the interaction. O cannot have a full description of the interaction of S with himself (O), because his information is correlation, and there is no meaning in being correlated with oneself. [12, p. 15]

Rovelli thus argues that it is impossible for a system to have information about itself because it requires it to stand in a particular correlation to itself and this is not possible. It is not a new idea that quantum mechanics cannot describe the observers and Rovelli also refers to a theorem by Breuer [2] that rules out the possibility of a system performing a complete self-measurement. Rovelli however seems to make the extra assumption that an observer cannot even meaningfully describe her own quantum state. This means that in RQM it is thus impossible for Wigner's friend F to give a description like (4) of the system $F + S$. And although not explicitly, the fact that F becomes correlated with S before measurement is still reflected in (2), because the unitary evolution of the system with respect to the observer breaks down. So (2) in fact does not completely overlook the correlation.

For what follows, we can take the standard quantum mechanics perspective and assume that (4) accurately describes the measurement from F's point of view. Even if we do this, Laudisa's claim that E' is the same sequence as E under the 'assumption that the correlation between O and s is taken explicitly into account' [10, p. 222] is simply not true. This claim comes down to the point that (2) is basically the same sequence as (3) if we would take the correlation between F and S into account. I argued above that if we take the correlation between F and S into account, we however get something like (4). We then see that (4) is still a different state evolution than (3). The evolution described in (3) says that at the end of the measurement, $S + F$ would be in the state: $\frac{1}{\sqrt{2}}|up\rangle \otimes |F - up\rangle + \frac{1}{\sqrt{2}}|down\rangle \otimes |F - down\rangle$. The evolution described in (4) says that the state of $F + S$ at the end of the measurement is: $|up\rangle \otimes |F - up\rangle$.

Hence, according to (3), the system is still in a superposition and according to (4) the system has collapsed to S having spin up and F measuring that the spin is up. This is the essential problem with Wigner's friend: two observers give different accounts of what happens during the measurement! One observer applies the collapse postulate and the other does not. As I argued in Sect. 2, we in fact get a more direct contradiction between the two descriptions (3) and (4) than on Rovelli's analysis, because they concern the same quantum system $S + F$. So far, Laudisa's critique of Rovelli's formulation of the Wigner-friend story therefore seems illegitimate. Either he should be willing to drop the claim that (3) and (4) are the same sequence, or he should clarify what is meant by the 'assumption that the correlation between O and s is taken explicitily into due account' [10, p. 222].

The second part of the problem that Laudisa sees with Rovelli's account of Wigner's friend relates to Wigner's description of the measurement inside the lab. A description like (3) does not reflect any interaction between W and $S + F$, which, according to Laudisa, would be required in RQM for W to be able to describe the combined system in the lab. Laudisa formulates the point as follows (P is the external observer outside the lab, i.e. W in our terms):

> As to the situation of the observer P, moreover, in the account of the third person problem there is a further element of ambiguity. For it is claimed that P 'describes' the system $s - O$ but without doing anything whereas, according to the role that RQM ascribes to the notion of information, there is no way of acquiring information without interaction (in terms of correlation). [10, p. 222]

Laudisa argues that it would follow from RQM that W needs to interact with $S + F$ in order to be able to describe it and that this should be reflected in the description made by W. Laudisa therefore proposes that W should give the following description of the measurement instead of (3) [10, p. 223]:

$$\begin{aligned}\left(\frac{1}{\sqrt{2}}|up\rangle + \frac{1}{\sqrt{2}}|down\rangle\right) \otimes |F - ready\rangle \otimes |W - ready\rangle \\ \Rightarrow \frac{1}{\sqrt{2}}|up\rangle \otimes |F - up\rangle \otimes |W - up\rangle \\ + \frac{1}{\sqrt{2}}|down\rangle \otimes |F - down\rangle \otimes |W - down\rangle\end{aligned} \tag{5}$$

Contrarily to what Laudisa claims, it is, however, not evident that it follows from RQM that the state spaces of W and $F + S$ should be combined at the end of the measurement. Suppose that it were possible in RQM for a system to have information about itself and that W would describe the evolution of both $S + F$ and W. It still would not imply that the state spaces of $S + F$ and W should be combined in RQM, because W did not perform an actual measurement on $S + F$.

Laudisa argues that, since in RQM it is the case that information can only be acquired by correlation, correlation should also be required in order for W to describe $F + S$. He refers to what Rovelli writes about this:

> The fact that the pointer variable in O has information about s (has measured A) is expressed by the existence of a correlation between the A variable of S and the pointer variable of O. The existence of this correlation is a measurable property of the O-s state. [12, p. 9]

We see here, however, that the phrase "O has information about s" is taken to mean that O has measured some variable A of s. This suggests that O can only have information about s relative to some specific variable. In the context of Wigner's friend we are concerned with the spin of S, which W did not measure. We can therefore say that W does not have information about $F + S$ with respect to spin.

Now it is true that W is required to know some things about what happens inside the lab in order to be able to give a description like (3). W needs to trust the fact that F will indeed perform a measurement on S and W needs to know the states of S and F before the measurement. Specifically, W needs to know that S starts in the superposition $\frac{1}{\sqrt{2}}|up\rangle + \frac{1}{\sqrt{2}}|down\rangle$ and that F is in the ready state $|F - ready\rangle$. This means that W can first do a check in the lab and verify that these are indeed the states in which F and S find themselves, let's say this is the case at t_0. W could make sure that

S is in a superposition by first measuring a property of the electron that is incompatible with its spin. W therefore would have information about S with respect to this other property.

But after checking the initial set-up, W will leave the lab, let's say at t_1, and will not be able to check the states of F or S anymore. The measurement will then occur at t_2. From outside the lab, W can still describe the time evolution of F and S from t_1 to t_2, but this is simply because he can use quantum mechanics to predict the state of $S + F$ relative to him if he would enter the lab. From t_1 to t_2, W is not acquiring any new information, he is just using his previously acquired knowledge that F will measure S to conclude that the state spaces of F and S will be combined.

We should thus carefully distinguish the possibility of *describing* the evolution of the state of a system from the act of *acquiring* new information about a system. The latter is only possible with physical interaction and the former is possible provided that the initial state of the system and the general course of action is known because of previous interaction. Since W does not need to acquire new information about $F + S$, a correlation between W and $F + S$ is not required at the moment at which the spin-measurement occurs. A description like (5) is therefore not correct.

I hold that we can conclude that Laudisa's critique of Rovelli's solution to Wigner's friend is not justified. Laudisa has argued that Rovelli should give a different analysis of the thought experiment and that if this is done, the problem with the Wigner's friend problem disappears. In this section I have first of all pointed out that according to Rovelli's notion of information, this alternative analysis is not possible. More importantly, I have shown that if F can describe the system $S + F$ with (4), we would still need to account for the fact that (3) and (4) are fundamentally different descriptions of the measurement. I have also shown that in RQM it is not required that W interacts with $F + S$ in order to be able to describe the measurement that F performs on S.

5 Conclusion

To sum up, a few points have been clarified in this paper. Although it is possible to analyze Wigner's friend differently than Rovelli has done, I have shown in Sect. 4 that we do not need to accept the analysis that is proposed by Laudisa. We have seen that, even if we assume the standard quantum mechanics perspective and include the correlation between F and S in the description of the measurement from the friend's point of view, it will still end in a definite state. We also saw that it does not follow from RQM that Wigner should interact with $F + S$ in order to describe the measurement. Hence, the description given by the friend of the system $S + F$ is different from the description given by Wigner of $S + F$. This means that RQM's solution of Wigner's friend is still a welcome one.

With respect to RQM itself, I proposed in Sect. 3 that in order to give a coherent interpretation, RQM should take the wave function to represent a real physical quantity, albeit a relative quantity. I argued that the relativization of quantum states is already sufficient to account for problems with nested measurement like Wigner's friend. Furthermore, what we can take away from the discussion of Laudisa's critique is that when

a measurement is made, new information is acquired, while a description made with the Schrödinger equation can be inferred from information that was acquired previously. It seems that it should be made more precise how the notion of information is relativized to properties. With respect to the discussion whether F can describe her own quantum state, it can also be made more clear why it is impossible in RQM for a system to have information about itself.

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