Reassessing the strength of a class of Wigner's friend no-go theorems

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Two recent, prominent theorems—the "no-go theorem for observer-independent facts" and the "Local Friendliness no-go theorem"—employ so-called extended Wigner's friend scenarios to try to impose novel, non-trivial constraints on the possible nature of physical reality. While the former is argued to entail that there can be no theory in which the results of Wigner and his friend can both be considered objective, the latter is said to place on reality stronger constraints than the Bell and Kochen-Specker theorems. Here, I conduct a thorough analysis of these theorems and show that they suffer from a list of shortcomings that question their validity and limit their strength. I conclude that the "no-go theorem for observer-independent facts" and the "Local Friendliness no-go theorem" fail to impose significant constraints on the nature of physical reality.

1 Introduction

Recent years have seen a renewed interest in the Wigner's friend paradox. In particular, so-called extended Wigner's friend scenarios (EWFS) have been in vogue as means to display limits regarding the level of *objectivity* one can make use of while interpreting quantum theory. These EWFS consist of settings in which entangled systems are shared by sets of Wigner's friend arrangements; that is, they are made up of Bell-type experimental settings, in which the components of entangled systems are sent to different labs, but with such labs enhanced with Wigner's friend arrangements, where the friend first measures the received component and then a 'superobserver' measures the whole lab.

The current surge in interest in EWFS has been somehow unsystematic, making it difficult to assess the real value of the different efforts and the relations among them. One useful way to classify them is as follows. On the one hand, there are those proposals which leave fixed the measurement settings of all observers involved, both friends and superobservers. The idea is to design the experiments in such a way that one employs, on a single run, measurement settings that, in a standard Bell-type scenario, would correspond to different possibilities. One then tries to employ the correlations among the results of all observers to set limits on possible interpretations of quantum theory. Efforts in this direction include the Pusey-Masanes (Pusey, 2016) and Żukowski-Markiewicz (Żukowski and Markiewicz, 2021) arguments, which try to challenge the objectivity of quantum measurement outcomes, and the Frauchiger-Renner theorem (Frauchiger and Renner, 2018), which allegedly shows that quantum theory does not apply at all scales. The problem with this type of arguments, though, is that the rely on a mistaken assumption regarding the correlations between the results of the friends and those of superobservers, rendering them invalid (see Okon (2022) for details).

On the other hand, there are proposals which, as in the standard Bell scenario, do allow for the observers to choose what measurement to perform. In particular, in these settings, on each run of the experiment, each superobserver only performs one of a list of possible measurements. Moreover, these proposals build their results only employing correlations among the results of the superobservers. This group includes the "no-go theorem for observer-independent facts" in Brukner (2018), as well as the "Local Friendliness no-go theorem" in Bong et al. (2020) (see also Cavalcanti and Wiseman (2021)). These theorems are the main subject of this assessment.

Building on Brukner (2015), the first (to my knowledge) to employ an EWFS, Brukner (2018) presents a "no-go theorem for observer-independent facts". To do so, he considers two Wigner's friend arrangements, sharing an entangled pair, and a particular sequence of measurements performed by the friends and the superobservers. Then, by positing four assumptions—'Universal validity of quantum theory', 'Locality', 'Freedom of choice' and 'Observer-independent facts'—he derives a theorem interpreted as showing that there can be no theory in which the results of both the superobservers and the friends can jointly be considered as objective properties of the world.

Bong et al. (2020), however, argues that Brukner's 'Observer-independent facts' assumption is equivalent to Kochen-Specker non-contextuality (KSNC) and that Brukner's result can be obtained from 'Freedom of choice' and KSNC alone (no 'Locality' required). Moreover, by arguing that the Kochen-Specker theorem already establishes that 'Freedom of choice' and KSNC lead to a contradiction with quantum mechanics, it is concluded that Brukner's theorem fails to set constraints on the objectivity of observations. Nevertheless, Bong et al. (2020) maintains that there is something of value in Brukner's arrangement and that, in fact, it can be used to derive a theorem by retaining his 'Freedom of choice' and 'Locality' assumptions, but replacing his 'Observer-independent facts' by what they call the 'Absoluteness of Observed Events' assumption. Since it is argued that the new set of assumptions is strictly weaker that those of Bell and Kochen-Specker theorems, the new result is advertised as placing strictly stronger constraints on physical reality than these old theorems.

Here, I perform a thorough analysis of the "no-go theorem for observer-independent facts" of Brukner (2018) and the "Local Friendliness no-go theorem" of Bong et al. (2020). Regarding the former, I show that it depends on a non-trivial hidden assumption and that it relies on a mistaken application of standard quantum mechanics to the EWFS considered.

As for the latter, I argue that it is not true that its assumptions are strictly weaker that those of Bell and that it relies on the same mistaken application of standard quantum mechanics. I conclude that the theorems fail to set interesting constraints on the possible nature of physical reality.

My manuscript is organized as follows. In section 2, I present an overview of the "no-go theorem for observer-independent facts" of Brukner (2018) and the "Local Friendliness no-go theorem" of Bong et al. (2020). Then, in section 3, I offer my assessment of such theorems. Finally, in section 4, I state my conclusions.

2 The theorems

We start with an overview of the "no-go theorem for observer-independent facts" in Brukner (2018) and the "Local Friendliness no-go theorem" in Bong et al. (2020).

2.1 The no-go theorem for observer-independent facts

Elaborating on Brukner (2015)—the first to consider a Bell-type scenario supplemented with Wigner's friend arrangements—Brukner (2018) asks whether there exists a theory, possibly different from quantum theory, in which the results of both Wigner and his friend can jointly be considered observer-independent, objective facts of the world. The question is given a negative answer with the introduction of a "no-go theorem for observer-independent facts".

To construct the theorem, Brukner considers an EWFS with two Wigner's friend arrangements—lab 1 with Charlie inside and Alice outside and lab 2 with Debbie inside and Bob outside—each receiving a particle of an entangled pair. Inside their labs, Charlie and Debbie perform spin measurements along direction z. Let's denote by $\left|Z_{\pm}\right\rangle_i$ the state of lab i after the friend measures the spin along z and finds the result $\pm$. Then, Alice and Bob perform, on their respective labs, one of two measurements: a "Z measurement" in basis $\{\left|Z_+\right\rangle_i, \left|Z_-\right\rangle_i\}$ or an "X measurement" in basis $\{\left|X_+\right\rangle_i = \frac{1}{\sqrt{2}}\left(\left|Z_+\right\rangle_i + \left|Z_-\right\rangle_i\right), \left|X_-\right\rangle_i = \frac{1}{\sqrt{2}}\left(\left|Z_+\right\rangle_i - \left|Z_-\right\rangle_i\right)\}$. That is, on each run of the experiment, each superobserver only performs one of these two possible measurements.

The setting described above is used by Brukner to argue for the mutual incompatibility of four assumptions: (1) 'Universal validity of quantum theory', establishing that quantum predictions hold at any scale; (2) 'Locality', requiring that the choice of measurement on one side has no influence on the outcomes of the other; (3) 'Freedom of choice', stipulating statistical independence between measurement settings and the rest of the experiment and (4) 'Observer-independent facts', demanding for there to exist a joint assignment of truth values to propositions about the outcomes of all observers. In particular, according to Brukner, this last assumption implies that the statements he calls A_1: "the pointer of Charlie's apparatus points to result +" and A_2: "after performing an X measurement, the pointer of Alice's apparatus points to result X_-", have well-defined truth values. That is, all such statements are assumed to have truth values, regardless of what measurements the superobservers decide to perform.

The incompatibility among Brukner's assumptions is shown as follows. He denotes by A_1 and A_2 the two measurement settings of Alice, which correspond to the observational statements Charlie and Alice can make about their respective outcomes (analogously with B_1 and B_2 for Bob and Debbie). Then, it is noted that assumptions (2), (3) and (4) imply the existence of local hidden variables, which determine A_1, A_2, B_1 and B_2 (with values ± 1). Moreover, it is noted that these assumptions imply the existence of a joint probability distribution, $p(A_1, A_2, B_1, B_2)$, whose marginals (e.g., $p(A_1, B_2) = \sum_{A_2, B_1} p(A_1, A_2, B_1, B_2)$) satisfy the CHSH inequality: $E(A_1, B_1) + E(A_1, B_2) + E(A_2, B_1) - E(A_2, B_2) \leq 2$ (with, e.g., $E(A_1, B_2) = \sum_{A_1, B_2} A_1 B_2 p(A_1, B_2)$). The problem is that there exist entangled states to be distributed among the two labs, such as

$$\frac{1}{2}\left[\sin(\pi/8)\left|+_z, +_z\right\rangle + \cos(\pi/8)\left|+_z, -_z\right\rangle - \cos(\pi/8)\left|-_z, +_z\right\rangle + \sin(\pi/8)\left|-_z, -_z\right\rangle\right], \qquad (1)$$

which lead to quantum predictions that violate the CHSH inequality. Since the assumptions are shown to be inconsistent, the conclusion reached by Brukner is that there can be no theoretical framework where the results of different observers can jointly be considered objective facts of the world.

2.2 The Local Friendliness no-go theorem

The starting point of the "Local Friendliness no-go theorem" presented in Bong et al. (2020) (see also Cavalcanti and Wiseman (2021, section 4)), is an analysis of Brukner's "no-go theorem for observer-independent facts". According to Bong et al. (2020), Brukner's 'Observer-independent facts' assumption demands propositions about all observables *that might be measured*, by an observer or a superobserver, to be assigned a truth value independently of which measurements the superobservers perform. That is, they read Brukner's assumption as implying, for instance, that even when Alice performs a Z measurement, statements regarding the result of Alice's *unperformed* X measurement have well-defined truth values.

Given this reading, they argue that Brukner's 'Observer-independent facts' assumption is, in fact, equivalent to Kochen-Specker non-contextuality (KSNC). Moreover, they argue that such an assumption, together with 'Freedom of choice', are sufficient to derive Brukner's result. Since the Kochen-Specker theorem already establishes that 'Freedom of choice' and KSNC are incompatible with quantum mechanics, they conclude that the 'Observer-independent facts' assumption plays no role in the theorem so, in the end, it fails in its mission to place limits on the objectivity of facts.

Still, according to Bong et al. (2020), Brukner's arrangement is valuable and, in fact, can be used to derive a strong result. To do so, echoing Brukner, they consider two perfectly isolated vaults, one containing Charlie and the other Debbie, each receiving a particle of an entangled pair. Charlie and Debbie then perform spin measurements on a fixed basis, obtaining outcomes C and D. Then, Alice and Bob perform measurements X and Y, selected out of a list of possible measurements, on Charlie's and Debbie's vaults, respectively. Their outcomes are denoted A and B. The possible measurements by Alice are described as follows. If $X = 1$, Alice opens Charlie's vault, asks him what he observed and sets her result equal to that of Charlie. If $X \neq 1$, Alice performs a measurement on the contents of the whole vault, including Charlie, in a basis incompatible with the one used by Charlie. This can be done, it is argued, by reversing the unitary evolution that entangled Charlie and his apparatus with his particle, and performing a measurement on the particle alone on a different basis (the possible measurements by Bob are obtained by substituting X for Y and Charlie for Debbie).

To analyze this setup, Bong et al. (2020) introduces three assumptions: 'Absoluteness of Observed Events' (AOE), 'No-Superdeterminism' (NSD) and 'Locality' (L). The conjunction of these three assumptions is then called 'Local Friendliness' (LF). These assumption are described as follows.

The idea behind AOE is that every observed event exists absolutely, not relatively. That is, that performed experiments have observer-independent, absolute results. For the experiment under consideration, this implies that, in each run, there exists a well-defined value for the result observed by each observer; i.e., in each run, there is a well-defined value for A, B, C and D. This, in turn, implies the existence of a joint probability distribution, $P(ABCD|XY)$, from which the joint probability for the results of Alice and Bob, $P(AB|XY)$, can be obtained. Moreover, the joint probability distribution must ensure consistency between the outcomes of friends and superobservers when $X, Y = 1$. Given all this, for the experiment considered, AOE is formalized as follows:

- ∃ P(ABCD|XY) such that

  i. $P(AB|XY) = \sum_{C,D} P(ABCD|XY) \quad \forall \quad A, B, X, Y$

  ii. $P(A|CD, X = 1, Y) = \delta_{AC} \quad \forall \quad A, C, D, Y$

  iii. $P(B|CD, X, Y = 1) = \delta_{BD} \quad \forall \quad B, C, D, X$.

The motivation for NSD is the idea that the experimental settings can be chosen freely. It is argued to be a formalization of the 'Freedom of choice' assumption used to derive Bell's theorem, and is stated as follows: "any set of events on a space-like hypersurface is uncorrelated with any set of freely chosen actions subsequent to that space-like hypersurface". In the experiment under consideration, and assuming AOE, NSD is taken to imply that C and D are independent of the choices X and Y; that is:

- $P(CD|XY) = P(CD) \quad \forall \quad C, D, X, Y$.

Finally, L prohibits the influence of local settings on distant outcomes. That is, it is the assumption usually called 'Parameter independence'. In Bong et al. (2020), it is enunciated as follows: "the probability of an observable event e is unchanged by conditioning on a space-like-separated free choice z, even if it is already conditioned on other events not in the future light-cone of z". For the experiment in question, and assuming AOE, L is said to imply:

- $P(A|CDXY) = P(A|CDX) \quad \forall \quad A, C, D, X, Y$
- $P(B|CDXY) = P(B|CDY) \quad \forall \quad B, C, D, X, Y$.

The construction of the theorem then proceeds in two steps. On the one hand, it is shown that the LF assumptions imply a set of constraints on the joint probability for the results of Alice and Bob, $P(AB|XY)$. Such constraints are expressed in the form of the "LF inequalities". On the other hand, it is argued that if a superobserver can perform arbitrary quantum operations on an observer and its environment—that is, if quantum evolution (including quantum measurement) is controllable on such a scale—then quantum mechanics predicts the violation of the LF inequalities. In other words, if the quantum operations required by the experiment can, in principle, be performed, then quantum mechanics predicts the violation of the LF inequalities.

With all this in mind, by defining a 'physical theory' as "any theory that correctly predicts the correlations between the outcomes observed by the superobservers Alice and Bob", the LF theorem is stated in Bong et al. (2020) as follows:

> **LF Theorem**: If a superobserver can perform arbitrary quantum operations on an observer and its environment, then no physical theory can satisfy the LF assumptions.

Regarding the LF inequalities, it is noted that, for the specific experiment considered by Brukner—in which the superobservers only have two binary-outcome measurement options—the set of LF correlations is identical to those allowed by Bell. This, however, is not the case in general. In more complicated scenarios, in which, for instance, the superobservers have more than two measurement choices or measurements with more than two possible outcomes, the set of LF correlations can be larger than the set of Bell correlations. In fact, it is argued that, for a given scenario, the set of LF correlations strictly contains the set of Bell correlations. This implies that, for a given scenario, it is possible for quantum correlations to violate a Bell inequality, while satisfying all of the LF inequalities (but not the other way around).

An important claim in Bong et al. (2020) is that their theorem "places strictly stronger constraints on physical reality than Bell's theorem". To reach such a conclusion, they note that the derivation of the Bell inequalities requires NSD and 'Factorizability'. The latter, in turn, follows from the conjunction of 'Parameter independence' (here called L) and 'Outcome independence'. Moreover, they argue that the AOE assumption is necessary, although often left implicit, for the derivation of Bell's theorem. From this, they conclude that the LF assumptions are strictly weaker than the assumptions needed to derive Bell's theorem, which means that a violation of the LF inequalities would have stronger implications than violations of the Bell inequalities. Finally, it is pointed out that, as Bell's, the LF theorem is theory-independent, in the sense that its conclusions hold for any theory, as long as the quantum predictions are realized in the laboratory.

Regarding the realization of such a test, Bong et al. (2020) reports the violation of the LF inequalities in an experiment in which photon's paths play the role of observers. It is readily acknowledged that such an experiment is simply a proof of concept, and that a true test of the inequalities, with observers of adequate complexity, is well beyond present technology. However, it is argued that, if the friend were an artificial intelligence algorithm, simulated in a quantum computer, then there would be good reason to think that quantum mechanics would allow control of the type required.

3 Assessing the theorems

I'm finally in position to explore these theorems in detail. I start with an evaluation of Brukner's work.

3.1 Evaluation of the no-go theorem for observer-independent facts

The first observation I make is that the discussion in Brukner (2018) of the key 'Observer-independent facts' assumption is somehow ambiguous and allows for two different interpretations. To begin with, Brukner (2018) uses the symbols A_1, A_2, B_1 and B_2 for three different things: i) the settings of Alice and Bob, ii) their results and iii) certain observational statements, such as “after performing an X measurement, the pointer of Alice’s apparatus points to result X_-” (which is called A_2 in Brukner (2018)). On top of that, it is not actually clear whether what Brukner calls the observational statement A_1 (“The pointer of Wigner’s friend’s apparatus points to result $z+$”), refers to an observational statement uttered by Charlie, or by Alice when she performs a Z measurement. To see that Brukner (2018) is, in fact, ambiguous, we note that, on the one hand, he writes statements such as “A_1 and A_2 correspond to the observational statements Charlie and Alice can make about their respective outcomes”, in which case it seems clear that A_1 corresponds to an observational statement made by Charlie. However, since Brukner (2018) also uses A_1 and A_2 for Alice’s settings, it contains statements such as “Alice chooses between two measurement settings A_1 and A_2”, in which case A_1 no longer seems to be a statement made by Charlie, but a claim associated with Alice.

Why is this (apparently pedantic) issue important? The point is that these two possible readings regarding the statement A_1 lead to radically different contents for the ‘Observer-independent facts’ assumption. Let’s start with the second option, namely, that A_1 is a statement made by Alice. In that case, since the ‘Observer-independent facts’ assumption requires “an assignment of truth values to statements A_1 and A_2 independently of which measurement Wigner performs”, then the assumption would demand, not only for all performed experiments to have well-defined results, but also for (at least some) unperformed experiments to do so.

This, in fact, seems to be the interpretation of the ‘Observer-independent facts’ assumption offered in Bong et al. (2020) where, as we saw, it is taken as demanding propositions about all observables *that might be measured* to be assigned a truth value, independently of whether they where actually performed or not. That is, they read Brukner’s assumption as implying that, even when Alice performs a Z measurement, a statement regarding the result of her *unperformed* X measurement has to have a well-defined value. This is why, in Bong et al. (2020), it is concluded that the ‘Observer-independent facts’ assumption is equivalent to KSNC. However, even with this reading of Brukner’s assumption, it seems to me that this identification is illegitimate. KSNC is an assumption demanding for the results of all experiments to be independent of the *context* of the measurement and, in particular, independent of which other measurements were performed simultaneously. I fail to see how, by reading A_1 as a statement by Alice, the ‘Observer-independent facts’ is equivalent to demanding non-contextuality.

That is, KSNC would demand, for instance, for the result of Alice’s experiment to be independent of what Bob decides to measure but, by reading A_1 as a statement by Alice, the 'Observer-independent facts' demands, say, for the result of Alice's A_1 measurement to be well-defined, even if Alice measures A_2. Moreover, the KSNC is a demand for all results, of all possible experiments. It is not clear to me that the particular demand by Brukner, made for a specific experiment, could straightforwardly be read as setting such a strong demand for all possible all observables, in all possible experiments. In any case, it is important to clearly distinguish between a demand for experiments to yield observer-independent, absolute results—the motivation behind 'Observer-independent facts'—and a demand for all measurements to passively, context-independently, reveal previously possessed well-defined values—the motivation behind KSNC. Of course, the latter is a much stronger requirement, already ruled out by the Kochen-Specker theorem.

At any rate, I agree with Bong et al. (2020) that, by reading the 'Observer-independent facts' assumption this way, Brukner's no-go theorem fails to set relevant limits on the objectivity of facts. The point is that, by interpreting A_1 as a statement by Alice (and B_1 as a statement by Bob), Brukner, at best, sets constraints on framework demanding objectivity, not only of performed experiments, but also of unperformed ones. It seems clear to me that such a demand goes well beyond what is usually required of a framework which seeks to maintain objectivity, so letting go of such a strong demand does not seem problematic at all.

What about opting for the other interpretation of A_1, namely, taking A_1 as a statement uttered by Charlie? I begin by pointing out that, in spite of the ambiguities described above, this is by far the most natural reading of Brukner's 'Observer-independent facts' assumption and the one in line with Brukner's conclusions. As we saw, he takes the theorem to show that there can be no framework where the results of Wigner and his friend can jointly be considered objective facts of the world. Therefore, it seems clear that what he has in mind is that the observational statement made by Charlie has a well-defined truth value, even if Alice decides to perform a Z measurement. Let's explore the import of Brukner's theorem, given this interpretation of A_1.

The starting point in the construction of the theorem is the observation that the 'Observer-independent facts' assumption implies the existence of the joint probability distribution $p(A_1, A_2, B_1, B_2)$. It is important to note, though, that, given the interpretation of A_1 (and B_1) under consideration, this would mean the existence of a joint probability distribution for the results of all four observers, Charlie, Alice, Debbie and Bob, in a run in which Alice and Bob decide to perform an X measurement—as opposed to a distribution for two possible results of Alice and two of Bob. That is, the 'Observer-independent facts' assumption implies the reality of those particular four results of all four observers, so there must be a joint probability distribution for them. Since this is so, the marginals, expectation values and the CHSH inequality constructed out of $p(A_1, A_2, B_1, B_2)$ must also refer to these four particular measurements.[1] The problem, though, is that Brukner proceeds to compare such results with the quantum predictions, not for those four measurements, but for the two possible results of Alice and the two possible results of Bob. That is, even though, at the beginning, he interprets A_1 and B_1 as observational statements made by Charlie and Debbie, in the end, he takes A_1 and B_1 to be the results of Alice and Bob, when they chose to perform a Z measurement.

There is, then, a *hidden assumption* behind the derivation of the theorem in Brukner (2018), namely, that the results of Alice and Bob, when they perform a Z measurement, necessarily coincide with the results previously obtained by Charlie and Debbie, respectively. This might seem like a completely trivial assumption but, in fact, it is not. For instance, it is not even true for pilot-wave theory, the paradigmatic observer-independent framework. We already saw that, for the construction of the theorem in Bong et al. (2020), such an assumption is made explicit (see items ii and iii of the AOE assumption). Therefore, I postpone a detailed discussion of the issue until I explore the LF theorem. For now, I just note the presence of this implicit, non-trivial assumption in Brukner (2018), without which the theorem cannot be derived.

The next observation I make is related with the last step in the derivation of the theory, namely, the comparison with quantum predictions. According to Brukner (2018), there are entangled states to be distributed among the two labs, such as that in Eq. (1), which lead to quantum predictions that violate the CHSH inequality. While this, of course, is the case for a standard Bell-type experiment, this does not automatically mean that this is also the case for the novel EWFS considered by Brukner, containing four agents and, in particular, two superobservers performing measurements over whole labs. One must be careful, then, to have in mind what is the correct *physical interpretation* of the expectation values in a given CHSH inequality—and not because the quantum predictions violate such an inequality for a given experimental scenario, it means that they do so for others.

So what about the quantum predictions for Brukner's scenario? The problem is that, since it involves intermediate measurements by Charlie and Debbie, such predictions crucially depend on what exactly happens during measurements. The issue, of course, is that the standard interpretation is hopelessly vague in that respect (Bell, 1990). The upshot is that *standard quantum mechanics is simply unable to make concrete predictions for the scenario considered*—the measurement problem gets in the way. That is, the Wigner's friend scenarios under consideration are precisely the type of settings for which one cannot get away with pressing on, adopting an operational stance and ignoring the conceptual limitations of the

[1] This is, in fact, the exact construction employed in the Pusey-Masanes argument, (Pusey, 2016; Okon, 2022).

standard framework.

It is often (implicitly or explicitly) assumed that a correct application of standard quantum mechanics to a Wigner's friend scenario means that Wigner must describe the laboratory, and all of its contents, as evolving unitarily—allegedly in accordance with the quantum rule for the evolution of isolated systems. This, presumably, is what Brukner has in mind with his 'Universal validity of quantum theory' assumption. It is not clear to me, though, that standard quantum mechanics contains such a rule and, if so, that this would be a correct application of it. In any case, one could simply *stipulate* that the laboratory and all of its contents evolve unitarily, even during the measurements of the friends. The issue is that Brukner (2018) also wants to assume that measurements yield objective results, but we know from Maudlin (1995) that those two assumptions, unitarity and objective outcomes, are incompatible with another assumption inherent to the standard framework: that the physical description given by the quantum state is complete. Therefore, on pain of inconsistency, it is simply impossible to assume unitarity and objective outcomes, and to employ the standard framework to make predictions. One can, of course, employ a framework which solves the measurement problem to make predictions. The issue is that different ways of doing so lead to different predictions for the scenario in question. For instance, while pilot-wave does predict a violation of the CHSH inequality, objective collapse models to not (see Okon (2022) for details).

A final comment regarding the conclusions in Brukner (2018). We saw that the theorem is interpreted as showing that there can be no theoretical framework where the results of different observers can jointly be considered objective facts of the world. However, even ignoring all the problems described above, and taking the result as valid, it is not clear why would one be forced to discard the 'Observer-independent facts' assumption, as Brukner suggests. At best, the theorem would demand for (at least) one of its assumptions to be abandoned, without pointing to any one of them in particular.

Taking stock, the no-go theorem for observer-independent facts in Brukner (2018) depends on a non-trivial, hidden assumption demanding for the Z measurement results of Alice and Bob to coincide with those of Charlie and Debbie. Moreover, there is no such thing as the correct quantum predictions for the proposed experiment, so there is no quantum benchmark with which to compare the predictions of models satisfying the imposed constrains—namely, the four assumptions in Brukner (2018) plus the hidden one mentioned above. That is, the constraints imposed on frameworks satisfying these assumptions are not really in conflict with quantum predictions. Below I will show that the theorem in Bong et al. (2020) suffers from quite similar issues. I delay a full assessment of the impact of these limitations on the validity, significance and strength of these theorems until after the detailed evaluation of the

"Local Friendliness no-go theorem", to which we turn next.

3.2 Evaluation of the Local Friendliness no-go theorem

I start with a simple, intuitive proof of the LF inequality, for the particular case when Alice and Bob only have two binary-outcome measurement options—in which case the LF inequality coincides with the CHSH inequality. Consider the LF setting and an ensemble of runs for which Alice and Bob choose $X, Y = 2$. By AOE, there is a joint probability distribution for the results of all observers and, by Fine's theorem (Fine, 1982), the expectation values of products of results, calculated with the marginals of such a joint probability distribution, satisfy the CHSH inequality

$$\langle C_2 D_2 \rangle + \langle C_2 B_2 \rangle + \langle A_2 D_2 \rangle - \langle A_2 B_2 \rangle \leq 2 \tag{2}$$

with, e.g., $\langle C_2 B_2 \rangle$, the expectation value of the product of the results of Charlie and Bob, when $X, Y = 2$.

Next, we employ the LF assumptions to transform this inequality, involving results of all four observers, into the CHSH inequality for the results of Alice and Bob. In particular, we note that

$$\langle C_2 D_2 \rangle \overset{\text{NSD}}{=} \langle C_1 D_1 \rangle \overset{\text{AOE}}{=} \langle A_1 B_1 \rangle \tag{3}$$

and that

$$\langle C_2 B_2 \rangle \overset{\text{L,NSD}}{=} \langle C_1 B_2 \rangle \overset{\text{AOE}}{=} \langle A_1 B_2 \rangle \tag{4}$$

$$\langle A_2 D_2 \rangle \overset{\text{L,NSD}}{=} \langle A_2 D_1 \rangle \overset{\text{AOE}}{=} \langle A_2 B_1 \rangle . \tag{5}$$

That is, we see that NSD and L allow the identification of certain expectation values with the same observers, but different settings, and that AOE and, in particular, conditions ii and iii, allow us to substitute, under the right circumstances, Alice for Charlie and Bob for Debbie. Putting everything together,

$$\langle A_1 B_1 \rangle + \langle A_1 B_2 \rangle + \langle A_2 B_1 \rangle - \langle A_2 B_2 \rangle \leq 2. \tag{6}$$

Next, I point out that, while standard proofs of Bell's theorem explicitly allow for the probabilities to change from run to run (through their dependence on what is usually denoted by λ), Bong et al. (2020) does not allow for such a change—they explicitly take the results of the friends to play the role of hidden variables, but do not allow for additional variables that could alter the joint probability distribution from run to run. This might seem like a strong and problematic assumption, and it is, but the issue is relatively easy to remedy.

One can think of Bell's λ as codifying whatever characterizes the complete state of the system to be measured in each run. If, as in original formulations of Bell's theorem, in all runs one prepares the same quantum state (e.g., a singlet), then λ summarizes whatever else changes besides the preparation of the initial state. In contrast, if as in Bong et al. (2020), one does not want to impose the same preparation for all runs, then λ would codify the preparation employed in each run, plus whatever else changes in that run. In any case, the assumption of no variation of the joint probability distribution with λ, seems problematic. However, one can fix the problem by adding a dependency of the joint probability distributions on λ and averaging over it. It is important to point out, though, that for this procedure to work, one must assume, on top of the LF assumptions, the so-called 'Settings independence' assumption—which is another version of what they call 'No-Superdeterminism'. Such an assumption demands, for the distribution of λ over the whole ensemble of runs, to be statistically independent of the settings: $\rho(\lambda|X,Y) = \rho(\lambda)$. Note that $\rho(\lambda)$ is the actual distribution of physical states λ over the ensemble of measured systems, and not a probability distribution, so question regarding the existence or convergence of $\rho(\lambda)$ are easily answered in the affirmative.

The upshot is that, given settings independence, it is enough for the expectation values calculated with the joint probability distribution of each possible value of λ to satisfy the inequality, for the average of them, over λ, to do so. In other words, even if you allow for different runs to have different joint probability distributions, labeled by different λ, if each joint probability distribution satisfies the inequality, which it will if the LF assumptions are imposed, and settings independence is the case, then the predictions of these models, averaged over λ, will also satisfy the inequality. Let's move on the evaluation of the theorem.

3.2.1 The 'Absoluteness of Observed Events' assumption

Above we saw that the starting point of the LF theorem is a critique of Brukner's 'Observer-independent facts' assumption, which leads to its substitution by LF's AOE. Such an assumption demands for all performed experiments to have observer-independent results which, for the experiment under consideration, implies the existence of a joint probability distribution, $P(ABCD|XY)$. Moreover, such a joint probability distribution is demanded to ensure consistency between the outcomes of friends and superobservers when $X, Y = 1$.

I argued, however, that the critique in Bong et al. (2020) seems to depend on a particular, arguably not very natural, reading of an ambiguous element in Brukner's presentation. In particular, they read Brukner (2018) as demanding all measurements that might be performed to have well-defined values, but it is more natural to read it as demanding all performed experiments to have well-defined values, which seems equivalent to what

AOE demands. We also saw that Brukner's derivation of the theorem depends on a hidden assumption, to the effect that the results of Alice and Bob, when they perform a Z measurement, necessarily coincide with the results previously obtained by Charlie and Debbie. It seems, then, that this hidden assumption is identical to the demand of consistency between friends and superobservers imposed by conditions ii and iii in AOE. I conclude that, by adopting the most natural interpretation of Brukner's claims, AOE is exactly equivalent to the conjunction of Brukner's 'Observer-independent facts' with his hidden assumption.

All this makes it clear that the AOE assumption contains two *independent* parts: 1) the claim that there is a joint probability distribution for all results and 2) conditions ii and iii, which have to do with the particular case in which Wigner measures in the same basis as his friend. Moreover, I want to argue that, while Bong et al. (2020) take both parts as necessary demands in order to ensure for observed events to be considered observer-independent or absolute, it is only the first part that is required to enforce absoluteness of observed events. The key issue to have in mind is that, even when Wigner and his friend measure "in the same basis" (e.g., $X, Y = 1$), it is never the case that what they are comparing are the result of the exact same measurement (I use the quotations to emphasize the fact that friends and superobservers perform measurements on different systems so, strictly speaking, the bases cannot be the same). As a result, a demand for absoluteness of observed events does not necessarily imply a demand for these two measurements to yield the exact same result. Let's discuss this issue with some care.

I start by noting that there are alternative ways to describe a measurement by Wigner when he measures "in the same basis" as his friend, and that some of them may elicit incorrect impressions. For instance, according to Brukner (2018), Alice and Bob might perform a "Z measurement" in basis $\{|Z_+\rangle_i, |Z_-\rangle_i\}$ with $|Z_\pm\rangle_i$ the state of whole lab i after the friend measures the spin along z and finds the result $\pm$. However, according to Bong et al. (2020), if $X = 1$, Alice opens Charlie's vault, asks him what he observed and sets her result equal to that of Charlie. The issue is that, portraying the measurement of Alice as her simply opening the door and asking Charlie the result, incorrectly conveys the idea that the measurement in question is quite mundane while, of course, it is not. The experiments considered assume that Charlie's vault is absolutely isolated from the outside world, so any intuitions we might have regarding everyday experiences of opening doors and asking colleges about results obtained in previous experiments, should not be interpreted as reasonable constraints on the set of models considered. In particular, in the same way that a measurement of a superobserver in a different basis might fully erase all records (including memories) of a previous measurement, a measurement "in the same basis" might also do so.

Another way to see this, is to point out that, when the measurements by Alice and

Bob are described in Bong et al. (2020), they are treated differently, depending on whether they measure "in the same basis" than the friend or not. As we saw, when they do, the measurements are described as they simply opening the door. However, when they measure in a different basis, it is argued that the measurement can be thought of as one in which Alice and Bob undo the measurement of the friend, and measure the particle again directly. For starters, it is clear that this description is available only by assuming that the measurements are *reversible*, which might not be the case for some models. Moreover, if measurements are reversible, even when Alice and Bob measure "in the same basis" as the friend, one could think of the measurement as them undoing the friend's measurement, thereby fully erasing all records of the friends' results (including their memories) and then measuring the particle again in the same basis. Put like this, it is not unreasonable to think of models in which the results of Alice and Bob do not necessarily coincide with the friend's, even when they measure in the same basis.

In fact, as mentioned above, this non-necessary coincidence between the measurements of, say, Bob and Debbie, when they measure in the same direction, is actually the prediction of pilot-wave theory, the preeminent, realist, objective quantum framework. As shown in Okon (2022, Appendix A), if one models the experimental arrangement in Bong et al. (2020) employing pilot-wave theory, one finds the correlation between the results of, say, results of Bob and Debbie along the same direction, to be a function of the measurement setting employed by Alice—with possible settings of Alice completely erasing the correlation between Bob and Debbie. Then, according to pilot-wave, it is not the case that Bob and Debbie necessarily obtain the same result when they measure along the same direction. That is, pilot-wave theory violates conditions ii and iii of AOE. Does this mean that such a framework is not sufficiently objective? I certainly do not think so.

In sum, the AOE assumption contains two independent parts, one demanding for there to be a joint probability distribution for all results and another demanding consistency between the results of Wigner and his friend when they both measure "in the same basis". And, while the first part does seem to be a reasonable demand to make in order to attain objectivity of observed results, the second part seems like too strong a demand, not even true in existing frameworks widely regarded as realist and objective.

As I mentioned in section 2.2, an important, far-reaching claim in Bong et al. (2020) is that their theorem "places strictly stronger constraints on physical reality than Bell's theorem". To arrive at this claim, first it is argued out that, although usually left implicit, the AOE assumption is necessary for the derivation of Bell's theorem. Then, it is pointed out that, while the derivation of the LF inequalities require AOE, NSD and L, the derivation of the Bell inequalities requires AOE, NSD, L and 'Outcome independence'. Since, according to this reasoning, the LF assumptions are a subset of Bell's assumptions, it is concluded that it is logically impossible to construct a model that allows violation of the LF inequality, but does not allow violation of Bell's inequalities.

I contend, though, that the AOE assumption is *not* necessary for the derivation of Bell's theorem. Therefore, it is not the case that the LF theorem is strictly stronger than Bell's theorem. As we saw, the AOE assumption involves two independent parts; and, while it seems true that demanding for results to be objective is, in fact, a necessary (implicit) supposition behind Bell's result, a demand of consistency between the results of friends and superobservers, is not required for the derivation of Bell's theorem. In fact, Bell's experimental scenario does not even involve friends and superobservers, so any condition constraining the relation between the results of friends and superobservers, seems fully irrelevant.

One could argue that Bell's experiment indeed involves sequences of observations, in the sense that it contains any number of "intermediate" measurements. For instance, a detector measures a particle, the detector is measured by a computer, the computer is measured by an observer, etc. Moreover, it could be argued that, if at any stage in that chain, the measurement does not simply reproduce the preexisting data, then a model satisfying all of Bell's assumptions would be able to violate his inequality at some stage. That is, it could be argued that we always assume that the records we read on a computer are accurate records of the detector measurements at some earlier time and that, without such an assumption, one could have a model satisfying Bell's assumptions, but breaking the inequality. The conclusion, then, is that conditions ii and iii in AOE are necessary to prove Bell's theorem.

This line of reasoning is mistaken. First of all, the step from, say, the computer recording the result, to an observer reading the result from the computer, does not seem to constitute an instance in which conditions ii and iii of AOE apply, as such conditions only deal with measurements by superobservers—i.e., situations in which decoherence is fully kept under control. More importantly, models satisfying Bell's assumptions are simply unable break the inequality at any stage, even if one allows for changes in the chain of observations. That is, a model satisfying Bell's assumptions will not display quantum correlations for the first measurements in the chain, and any number of *local* jumps in the chain on each side will *not* be able to produce quantum correlations in later steps of the chain. We conclude that, contrary to what is stated in Bong et al. (2020), conditions ii and iii in AOE are not necessary to prove Bell's theorem.

The idea that conditions ii and iii in AOE are necessary to prove Bell's theorem might be thought to be related with the so-called "collapse locality loophole" described in Kent (2005). The observation behind such a loophole is that, while Alice and Bob's measurements in Bell experiments are supposed to be performed at spacelike separation, in real experiments, there is some leeway as to where in spacetime the measurement outcomes actually arise. In particular, if one maintains, for instance, that measurements end until a human learns the result, then the measurements in all existing experiments are not spacelike separated. As a result, Kent points out that, if one considers models satisfying Bell's assumptions, but stipulating that human observation is required for measurements to end, then, in spite of all existing Bell experiments, one can argue that the inequalities have not been violated experimentally—opening the door for local models to be empirically adequate.

The point I want to make is that one must not confuse playing with the time at which measurements occur, which, following Kent, allows for experiments claiming violations of Bell's inequality to be questioned, with violations of conditions ii and iii, which do not modify when measurements happen, but allow for a variation of results in subsequent measurements. Consider, then, a model in which Bell's assumptions are satisfied, conditions ii and iii are violated, and in which it is stipulated that measurements fully end as soon as particles travel through the detector. Such a model is simply unable to break Bell's inequality and since, by construction, does not employ Kent's loophole, it is ruled out by existing Bell experiments.

In sum, conditions ii and iii of the AOE assumption are *not* necessary for the derivation of Bell's theorem. Therefore, in opposition to what is defended in Bong et al. (2020), it is perfectly possible to construct a model, which allows for a violation of the LF inequality, but does not allow for a violation of Bell's inequality. That is, it is perfectly possible to construct a non-local model that breaks conditions ii and iii of AOE, such that: it satisfies Bell's inequality in a standard Bell experiment, but breaks the LF inequality in Brukner's experiment. All one needs is a model, which yields quantum correlations for measurements of superobservers, but not for those of the friends. The fact that ii and iii are not satisfied by such a model, makes this perfectly possible.

In reply, it could be argued that it is not possible to perform Brukner's experiment without, at the same time, performing a Bell experiment. The point is that, in the end, the public data concerns the correlations $P(A,B|X,Y)$ between Alice and Bob, and this is, by construction, a Bell scenario. It is very important to recognize, though, that if one adopts this fully *operational* definition of what a Bell experiment consists of, one must also acknowledge that a model might behave very differently in different *concrete realizations* of a Bell scenario. For instance, one can consider Brukner's experiment and contrast it with what I would call a standard Bell experiment, i.e., one in which the two spin-$\frac{1}{2}$ particles of a singlet are sent to Alice and Bob for them to measure spin. Clearly, a model does not have to perform equally in both scenarios. For instance, as pointed out in Bong et al. (2020), objective collapse models break the inequality in the standard scenario, but satisfy it in Brukner's EWFS. Moreover, I take it that, when it is argued that it is logically impossible to construct a model that allows violations of the LF inequality, but does not allow violations of Bell's inequality, what is meant is that it is impossible to construct a model which violates the Bell inequality, in a standard Bell scenario, but which does not allow for violations of the LF inequalities, in Brukner's scenario. My claim is that it is perfectly possible to construct such a model.

3.2.2 A toy model

Consider a Brukner EWFS in which, for concreteness, the two entangled particles are prepared in a singlet. The toy model I have in mind is such that the state it assigns to the two particles is given by the standard quantum state associated with a singlet, together with a pair of randomly selected angles θ_1 and θ_2. Moreover, according to this model, when Charlie and Debbie measure the spin of their particles, three things happen. First, they obtain a result according to the following probabilities

$$P(C=1)=\cos^2\theta_1, \qquad P(C=-1)=\sin^2\theta_1 \tag{7}$$

$$P(D=1)=\cos^2\theta_2, \qquad P(D=-1)=\sin^2\theta_2. \tag{8}$$

Clearly, the results of Charlie and Debbie will not be correlated. Second, the values of θ_1 and θ_2 are updated according to the result obtained. Third, the state of Charlie and Debbie's labs gets entangled, though a purely unitary evolution, with the state of the incoming particles. Finally, according to this model, when Alice and Bob measure the state of Charlie and Debbie's labs, the model behaves exactly as an objective collapse model. That is, the measurement on one side causes a non-local collapse to an (approximate) eigenstate of the measured observable, leading to standard Bell-like quantum correlations for the results of Alice and Bob.

More generally, the proposed toy model is such that 1) the state of the prepared entangled pair is given by the quantum state plus a random pair of angles θ_1 and θ_2, 2) the results of direct measurements of the spin of the particles are governed by Eqs. (7) and (8), 3) after a measurement of spin, the angles are updated according to the result obtained, 4) such a measurement also causes the state of the particles to get entangled with the macroscopic measurement apparatus (and environment) and 5) when the particles get entangled with macroscopic objects, the results of Wigner's friend-type measurements on such macroscopic objects behave analogously to an objective collapse model. Above we saw that the measurements of the superobservers can also be thought of as they undoing the measurements performed by the friends and measuring the particles again directly. It could be objected that the proposed model would have trouble dealing with this way of performing the experiment. Note, however, that the idea of undoing the measurements of the friends presupposes for those measurements to be reversible. Since, in this model, the measurements of the friends are probabilistic, this alternative way of thinking about the measurements of the superobservers is simply unavailable.

What assumptions does this model satisfy? First, it is such that all experiments have observer-independent, absolute results. Therefore, in the context of Brukner's EWFS, there is a joint probability distribution for the results of all four observers. It is not the case, however, that the results of friends and superobservers must coincide when $X, Y = 1$ so, even tough observed results are absolute, conditions ii and iii and AOE are violated. Regarding NSD, since the probabilities for C and D are given by Eqs. (7) and (8), it is clear that they are independent of X and Y, so such an assumption is straightforwardly satisfied. As for L, since the results of Alice and Bob are governed in analogy with an objective collapse model, and since such models satisfy the 'Parameter independence' assumption (called L in Bong et al. (2020)), then this model also does so. Note, however, that objective collapse models do not satisfy the 'Outcome independence' assumption, so this model also fails to do so. This, of course, renders the the model non-local in Bell's sense.

What about the behaviour of the model in experiments? In a standard Bell experiment, the results are independently governed by θ_1 and θ_2, so they will not be able to break the inequality. In contrast, in an EWFS, when the superobservers measure, the results mimic an objective collapse model, so they certainly would violate the LF inequality. It is possible, then, to construct a model which satisfies Bell's inequality but violates the LF inequalities. Another way to put all this, is that a model violating or not the LF inequalities (in an EWFS) is independent of it violating or not Bell's inequality (in a standard Bell experiment). For instance, knowing that a model violates the LF inequality does not settle the question as to how it would perform in a standard Bell experiment. It is not the case, then, that the LF theorem "places strictly stronger constraints on physical reality than Bell's theorem".

3.2.3 The wording of the theorem

The next issue I would like to analyze has to do with the wording of the LF theorem. As we saw in section 2.2, the construction of the theorem has two parts. First, it is shown that models obeying the LF assumptions satisfy the LF inequalities. Second, it is argued for the following conditional: if the quantum operations required by the proposed experiment can, in principle, be performed, then the quantum predictions violate the LF inequalities. Putting everything together, by defining a 'physical theory' as "any theory that correctly predicts the correlations between the outcomes observed by the superobservers Alice and Bob", the LF theorem is stated as a conditional: if a superobserver can perform arbitrary quantum operations on an observer and its environment, then no physical theory can satisfy the LF assumptions.

I start by inspecting the definition of 'physical theory'. As we just saw, in 2.2, that notion is reserved for any theory that "correctly predicts" the correlations between Alice and Bob. But what are these "correct predictions"? Since, as already was established, standard quantum mechanics cannot produce actual predictions for the experiment in question, these "correct predictions" cannot be the quantum predictions. Therefore, the "correct predictions" must mean those that coincide with the actual, experimentally observed correlations, whatever they turn out to be. Of course, for all we know, these actual correlations can be anything. Therefore, in order to constrain them, 2.2 employs a conditional to the effect that, if a superobserver can perform arbitrary quantum operations on an observer and its environment, then the quantum predictions violate the LF inequalities. The idea being that, while, in general, it is true that there are no correct quantum predictions for the proposed experiment, if the antecedent of the conditional is fulfilled, i.e., if a superobserver can, in fact, perform arbitrary quantum operations on an observer and its environment, then unambiguous predictions can be produced. Moreover, the idea is that, in that case, such predictions violate the LF inequalities. The problem is that such a conditional is false.

To begin with, I find the operational tone of the antecedent of the conditional vague and inadequate. The antecedent in question is formulated in Bong et al. (2020) in a couple of different ways, one general and one particular to the EWFS in question. The general form, as we saw, asks for superobservers to be able to perform arbitrary quantum operations on an observer and its environment—that is, for quantum evolution (including quantum measurement) to be controllable on such a scale. The particular formulation demands for the quantum operations required by the proposed experiment to be performable, at least in principle. Either way, what is it exactly that the condition demands? Presumably, the idea is something like this. If, for instance, the measurement of one of the friends objectively breaks unitarity, then the superobserver would not be able to perform a quantum operation that maintains the friend (and her environment) in an entangled superposition corresponding to different observational states. That is, the fact that unitary is broken, is supposed to restrict the operations available to the superobserver.

It seems to me, however, that the fact that a measurement of a friend breaks unitarity is better understood as a feature of the internal dynamics of the model in question, and not really as a constraint on what operations the superobservers can or cannot perform. In other words, even if the measurements of the friends break unitarity, the superobservers are perfectly capable of performing the quantum operations required by the proposed experiment, namely, certain measurements on the corresponding labs—i.e., the breakdown of unitarity does not restrict the measurements available to the superobservers. It seems, then, that what the antecedent of the conditional needs to capture is a constraint on how macroscopic systems evolve during measurements. And, even though Bong et al. (2020) shies away from using these terms, what it seems to be actually demanded is for the evolution during those measurements to be purely unitary.

More importantly, even if the measurements of the friends involve purely unitarity evolution, and the superobservers are able to perform quantum operations that maintain the friends in coherent superpositions, that does not mean that the correlations predicted are going to break the LF inequalities. That is, even if the states of the labs, after the friends measure, are given by what quantum mechanics calls a coherent superposition of different observational states, it is not necessarily the case that the LF inequalities would be broken. As we saw already, standard quantum mechanics cannot make predictions for the EWFS in question. Therefore, to make predictions for them, it is necessary to come up with an alternative, non-standard framework, capable of doing so. The point I want to make is that the fact that one of these frameworks stipulates purely unitary evolution during measurements in no way implies that such a model predicts violations of the LF inequalities. As I said, these models must be non-standard alternatives to the standard framework and, as such, they can possess all sorts of non-standard features, including predictions that do not break the LF inequalities, even if superobservers are able to fully control the quantum states of the friends. We must not forget that the assumption that results are objective, together with the assumption of purely unitary evolution, implies the the existence of additional variables (Maudlin, 1995). And this additional variables can play a non-trivial role in the calculation of predictions, allowing for predictions that do not break the LF inequalities.

In sum, Bong et al. (2020) looks for a condition that would guarantee predictions that break the LF inequality and it tries to formulate it in terms of the operations the superobservers are able to perform. The problem is that such a proposal does not work and, more generally, there seems to be no simple condition that would achieve what they are looking for. The truth is that, to make predictions for these scenarios, alternatives to the standard framework are required and different models will make different predictions, without there being a single condition that could determine on which side of the LF inequalities the predictions of a model would land. Of course, what Bong et al. (2020) does show is that models satisfying the LF assumptions do not break the inequalities, but what is lacking is a way to stipulate what models are able to break them.

We can contrast all this with Bell's theorem. In that case, one has 1) that models satisfying Bell's assumptions satisfy Bell's inequality and 2) that standard quantum mechanics unambiguously predicts violations of the inequality. The theorem can then be paraphrased as “the predictions of local models are incompatible with those of quantum mechanics”. In the LF case, in contrast, one shows that models satisfying the LF assumptions satisfy the LF inequalities, but one cannot show that quantum mechanics predicts violations of the inequality—and it is not even clear how to characterize models that violate it. One is then only left with the connection between the LF assumptions and the LF inequality.

Now, it is of course true that, once Bell experiments have been performed, and clear violations of the inequalities have been observed empirically, the fact that standard quantum mechanics violates Bell’s inequality becomes almost irrelevant. With experimental violations of the inequality, what we now have is a much stronger claim, namely, that “the predictions of local models are incompatible with actual experiments”—a claim which is completely independent of quantum mechanics. Couldn’t one do the same with the LF inequalities? The issue is that, unlike Bell’s experiment, the one required to experimentally probe the LF inequalities, while presumably doable in principle, is unrealizable in practice (and will be so for the foreseeable future). It is true, then, that such experiments would set constraints on empirically viable models, but the fact that we are unable to actually perform them, greatly diminishes the force behind the LF result.

Summing up, in Bong et al. (2020) it is shown that models satisfying the LF assumptions satisfy the LF inequalities. However, contrary to what it is argued there, it is not the case that such assumptions are strictly weaker that those of Bell. Moreover, since quantum mechanics is unable to make predictions for the EWFS considered, there is no standard violating the LF inequalities, with which to contrast models satisfying the LF assumptions. Finally, the proposed experiment is, at this stage, no more than a gedankenexperiment, so the prospects of experimentally constraining LF models seem, at least for a long time, unattainable.

4 Conclusions

The “no-go theorem for observer-independent facts” and the “Local Friendliness no-go theorem” are taken by their authors to impose non-trivial constraints on physical reality. However, such theorems suffer from a list of shortcomings that question their validity and limit their strength. In this work, I have shown that the theorem in Brukner (2018) depends on a non-trivial, implicit assumption, regarding the relation between the results of friends and superobservers, and that it relies on the mistaken notion that standard quantum mechanics is able to make predictions for the EWFS considered.

As for the theorem Bong et al. (2020), I have shown that, contrary to what is alleged, it does not rest on assumptions that are strictly weaker that those of Bell. Moreover, it relies on the same mistaken application of standard quantum mechanics to the EWFS in question, so there is no standard with which to contrast models satisfying the LF assumptions. Finally, I note that the proposed EWFS is unrealizable in practice, a fact that greatly diminishes the force behind the LF result.

In the end, all these theorems offer is the fact that models satisfying a certain group of assumptions satisfy certain inequalities. However, without theoretical or experimental benchmarks with which to compare those models, the established fact sharply looses impact and relevance. I conclude that the theorems fully fail in imposing significant constraints on the possible nature of physical reality.

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