**UNBELIEVABLE similarities between Araújo et al’s ideas (2015) on quantum mechanics and my ideas (2002-2008)**

Gabriel Vacariu

[I investigate this article here]

[This conclusion indicates exactly my EDWs!!! So, the framework is UNBELIEVABLE similar to my EDWs! The authors avoid any contradiction introducing the “theory of causal witnesses” that represent the correspondences between EDWs, no more or less!!!]

**(2015)** [**Mateus Araújo**](https://arxiv.org/search/quant-ph?searchtype=author&query=Ara%C3%BAjo%2C+M)**,**[**Cyril Branciard**](https://arxiv.org/search/quant-ph?searchtype=author&query=Branciard%2C+C)**,**[**Fabio Costa**](https://arxiv.org/search/quant-ph?searchtype=author&query=Costa%2C+F)**,**[**Adrien Feix**](https://arxiv.org/search/quant-ph?searchtype=author&query=Feix%2C+A)**,**[**Christina Giarmatzi**](https://arxiv.org/search/quant-ph?searchtype=author&query=Giarmatzi%2C+C)**,**[**Časlav Brukner**](https://arxiv.org/search/quant-ph?searchtype=author&query=Brukner%2C+%C4%8C)**, *Witnessing causal nonseparability*, at** [**https://arxiv.org/abs/1506.03776v2**](https://arxiv.org/abs/1506.03776v2)

In this paper, I investigate UNBELIEVABLE similarities between Araujo et al.’s idea (2015) and my ideas (2002-2008)

Their abstract

Our common understanding of the physical world deeply relies on the notion that events are ordered with respect to some time parameter, with past events serving as causes for future ones. Nonetheless, it was recently found that it is possible to formulate quantum mechanics without any reference to a global time or causal structure. The resulting framework includes new kinds of quantum resources that allow performing tasks - in particular, the violation of causal inequalities - which are impossible for events ordered according to a global causal order. However, no physical implementation of such resources is known. Here we show that a recently demonstrated resource for quantum computation - the quantum switch - is a genuine example of "indefinite causal order". We do this by introducing a new tool - the causal witness - which can detect the causal nonseparability of any quantum resource that is incompatible with a definite causal order. We show however that the quantum switch does not violate any causal nequality.

[The reader can already see UNBELIEVABLE similarity between the framework of their approach and my EDWs!!!]

Our common understanding of the physical world deeply relies on the notion that events are ordered with respect to some time parameter, with past events serving as causes for future ones. Nonetheless, it was recently found that it is possible to formulate quantum mechanics without any reference to a global time or causal structure. The resulting framework includes new kinds of quantum resources that allow performing tasks - in particular, the violation of causal inequalities - which are impossible for events ordered according to a global causal order. However, no physical implementation of such resources is known. Here we show that a recently demonstrated resource for quantum computation - the quantum switch - is a genuine example of "indefinite causal order". We do this by introducing a new tool - the causal witness - which can detect the causal nonseparability of any quantum resource that is incompatible with a definite causal order. We show however that the quantum switch does not violate any causal nequality. (p. 1)

[In this paragraph, the authors indicate the wrong framework, that is, the world/Universe (unicorn world) where everything has been placed. Obviously, I showed that the unicorn world is wrong!]

It is therefore not completely clear what is the precise

relation between “quantum correlations with no

causal order”, which violate causal inequalities, and

physically implementable resources, such as the quantum

switch, which outperform causally ordered ones.

To understand this relation, a crucial observation is that

the causal inequalities are *device-independent* constraints:

they are formulated independently of the physics of the

systems or the specific apparatuses employed. On the

other hand, the tasks discussed in Refs. [7, 8] include

additional assumptions, as for example that in each laboratory

quantum systems of a definite dimension have

to be used. It is clear that, given additional restrictions,

it is more difficult for causally-ordered agents to perform

certain tasks and, consequently, it can be easier to

detect the lack of causal order in a physical resource. (p. 2)

[It is clear that the authors wants to replace the unicorn world with EDWs!]

The aim of the present work is to develop a general

framework for the device-*dependent* detection of causal

nonseparability. The central tool we introduce is what

we call a *causal witness*, which represents a set of quantum

operations, such as unitaries, channels, state preparations,

and measurements, whose expectation value

is non-negative as long as all the operations are performed

in a definite causal order, i.e., as long as only

causally separable resources are used. The observation

of a negative expectation value is thus sufficient to conclude

that the operations were not performed in a definite

order. The concept is analogous to that of entanglement witness: an observable that has a non-negative

expectation value for separable states but can have a

negative expectation value for specific entangled states.

We find that, for every causally nonseparable process,

it is possible to construct a causal witness that detects

it. Importantly, and differently from the case of entanglement

witnesses, it is possible to use this method to

write necessary and sufficient conditions for causal separability

in a form that can be checked efficiently using

semidefinite programming (SDP).

 The tools developed are applied to the study of the

quantum switch as a resource within the process matrix

formalism. We show that, indeed, the quantum

switch corresponds to a causally nonseparable process.

We show that the protocol of Ref. [7] can be reformulated

as a causal witness which detects the causal nonseparability

of the quantum switch. We also find new,

more efficient witnesses, which could be useful for experimental

implementations.

[The reader can already seen the UNBELIEVABLE similarity between the “causal witness” and my ED interactions!!! “Quantum switch corresponds to a causally nonseparables process” means EDWs!!!!]

In the general scenario we consider in this paper, *N*

parties *Ai* establish correlations by exchanging physical

systems between their laboratories. Each party opens

their laboratory only once to let an incoming system

enter and to send an outgoing system out; they can

act on these systems by performing an arbitrary operation

in their local laboratory, which can yield different

measurement outcomes. The causal relations between

the parties (i.e., the ordering of events) are not *a priori*

specified. The most general situation compatible with the assumption that *the operations performed in each local*

*laboratory can be described by the quantum formalism*

can be conveniently represented in the “process matrix”

formalism introduced in Ref. [13]. This extends the

“comb” formalism of Ref. [14], which describes causally

ordered quantum networks. The aim of the formalism

is to characterize all possible probability distributions

that can be obtained in our general scenario. The key

concept is that of a *process*, which can be understood as

the external resource determining the statistics of the local

operations, and which generalizes both the notions

of quantum state and of quantum channel. The *process*

*matrix* is a useful mathematical representation of such a

concept. We shall use these two terms interchangeably. (pp. 2-3)

[the reader can understand now that we have been already placed within the EDWs!]

The authors continue:

**A. Local operations**

Each party *A* acts in a *local quantum laboratory*, which

can be identified by an input Hilbert space H*AI* and

an output Hilbert space H*AO*. (p. 3)

The generalization of the notion of causal separability

to a larger number of parties, with arbitrary dimensions

of the output spaces, is not trivial. The reason is that

one can consider situations in which an agent, through

her local operations, could modify a classical variable

that determines the causal order of agents in her future.

In such a “classical switch”, operations would still be

causally ordered in each run of an experiment, but it

wouldn’t be possible to write the corresponding process

matrix as a mixture of causally ordered ones. As this

issue does not affect the cases treated here, we shall not

consider it further. A more detailed analysis will be

presented in an upcoming work [19]. (p. 5)

[we are here placed in one EW where we can find “causalities”!]

In this section we developmathematical tools to identify,

in the bipartite case, which process matrices are

causally separable and which are not. In analogy with

entanglement witnesses [20], we call a hermitian operator

*S* a *causal witness* (or *witness*, simply) if1

tr[*SW*sep] ≥ 0 (28)

for every causally separable process matrix *W*sep. This

definition is motivated by the separating hyperplane

theorem [21]: since the set of causally separable processes

is closed and convex, for every causally nonseparable

process matrix *W*ns there exists a causal witness

*SW*ns such that tr[*SW*ns*W*ns] < 0.

To construct a witness for a given nonseparable process,

we will start by characterizing the set of all causal

witnesses in terms of linear constraints on a convex

cone. (p. 5)

[There are already certain phenomena that belong to the same EW or ED phenomena that belong to EDWs!!! Words by words! There is a lot of mathematics in this paper, but the frameworks is UNBELIEVABLE similar to my EDWs! The authors writes about “B. Chiribella’s witness” – therefore I have of investigate this article too!]

**A. Device-independent causal relations**

We still consider a multipartite scenario in which a set

of *N* parties {*Ai*}*N*

*i*=1 are located in different, separated

laboratories. Each party can perform operations and

obtain measurement outcomes. Contrary to the previous

case however, we do not consider here any particular

physical description of what happens in each lab;

the “settings” for the operations in the different laboratories

and the measurement outcomes are labelled by

some classical variables *xi* and *ai* (with 1 ≤ *i* ≤ *N*), respectively;

for simplicity we assume that the *xi*’s and

*ai*’s take a finite number of values. Defining the vector

of settings ~*x* = (*x*1, . . . *xN*) and the vector of outcomes

~*a* = (*a*1, . . . , *aN*), the device-independent description of

the correlations established in such an experiment is encoded

in the conditional probability *P*(~*a*|~*x*).

Causal inequalities [13] are constraints on *P*(~*a*|~*x*) derived

from the assumption that there exists an underlying

causal structure defining the order between parties. (p. 13)

[we are already in EDWs!]

**VI. CAUSAL INEQUALITIES**

The notion of causal separability considered above

relies on the quantum description of the local laboratories.

One may ask what are the constraints imposed by

a definite causal structure regardless of the specific description,

or even the physics governing the devices performing

the local operations. To study such restrictions,

we will make use of so-called *causal inequalities* [13],

which bound the possible correlations that can be established

between events following a definite causal order.

The violation of a causal inequality gives a stronger,

device-independent signature of lack of causal order

than the measurement of a witness. It is natural to ask

whether it is possible to use the quantum switch to violate

a causal inequality; we show below that this is not

the case. (p. 13)

As causally separable processes can only generate

causal correlations, the violation of a causal inequality

can also be used to detect the causal nonseparability of

a process. While causal witnesses are *device-dependent*

and can only detect causal nonseparability if each party

trusts her operation’s implementation, causal inequalities

are completely *device-independent*: even if each party

distrusts her laboratory, they can still detect causal nonseparability

from the statistics of their experimental

outcomes, if those violate a causal inequality. While

for every causally nonseparable process there is causal

witness that will detect its nonseparability, there are

causally nonseparable processes cannot be used to violate

any causal inequalities: in the next subsection

we will prove that the quantum switch provides such

an example. There is an analogy here with entanglement

witnesses, which allow for a device-dependent

way of detecting entanglement, and Bell inequalities,

which provide a device-independent entanglement certification

– “nonlocality” [27]. The important difference

is that states violating Bell inequalities are physically

implementable, while no example of a physically

implementable process violating causal inequalities is

known. (p. 14)

[UNBELIEVABLE, but this is the relationship between EDWs!!!]

Therefore, the quantum switch represents an example

of a causally nonseparable process that can only

generate causal correlations, and hence cannot be used

to violate any causal inequality12. It is noteworthy that

all the examples of causally nonseparable processes for

which a physical interpretation is known, including

those generated by space-time superpositions [32], fall

into this category. This raises the question of whether

causally nonseparable processes that do violate causal

inequalities can be physically implemented at all. (p. 15)

**VII. CONCLUSION**

The process matrix formalism was originally conceived

as a rather speculative extension of quantum mechanics

to possibly include the indefinite causal structures

expected in a quantized theory of gravity [10].

The results of this work show that, in fact, it is a natural

framework to study a class of quantum resources

which cannot be captured by the circuit model, but

nonetheless are physically realizable and can provide

powerful computational advantages. We have shown

that the quantum switch, a recently demonstrated resource

for quantum computation, can be conveniently

represented as a causally non-separable process matrix.

We have also presented causal witnesses that can verify

the causal nonseparability of the switch. As they only

require performing unitaries in a “superposition of order”

and a final measurement of a control qubit, such

witnesses can be easily implemented in quantum-optics

setups, as the one employed in Ref. [9]. (p. 15)

The theory of causal witnesses developed here has

close resemblances with the theory of entanglement

witnesses. In both cases, one is interested in finding

ways to certify that a resource is outside some convex

set, the set of separable states in the latter case, that

of causally nonseparable process matrices in the former

case. Following this analogy, causal inequalities

can be seen as the counterpart to the Bell inequalities,

as they both provide device-independent tests regarding

the existence of some classical variable: local hidden

variables for measurement outcomes in one case, classical variables determining the causal order in the

other. A significant difference between the two frameworks

is that the problem of determining causal separability

can be solved numerically with efficient algorithms,

whereas characterizing entanglement has been

proven to be an NP-hard problem [33].

As one could expect from the analogy with entanglement,

there exist causally nonseparable processes that

cannot violate causal inequalities. What is striking, in

the case of process matrices, is that a physical interpretation

is known only for resources in this category. As

one of the main open problems in this field is the characterization

of physical process matrices, it is tempting

to speculate whether the (im)possibility to violate

causal inequalities could provide a useful guidance in

this respect.

[This conclusion indicates exactly my EDWs!!! So, the framework is UNBELIEVABLE similar to my EDWs! The authors avoid any contradiction introducing the “theory of causal witnesses” that represent the correspondences between EDWs, no more or less!!!]