The EPR-Bell experts: if we don't like locality, what's left?

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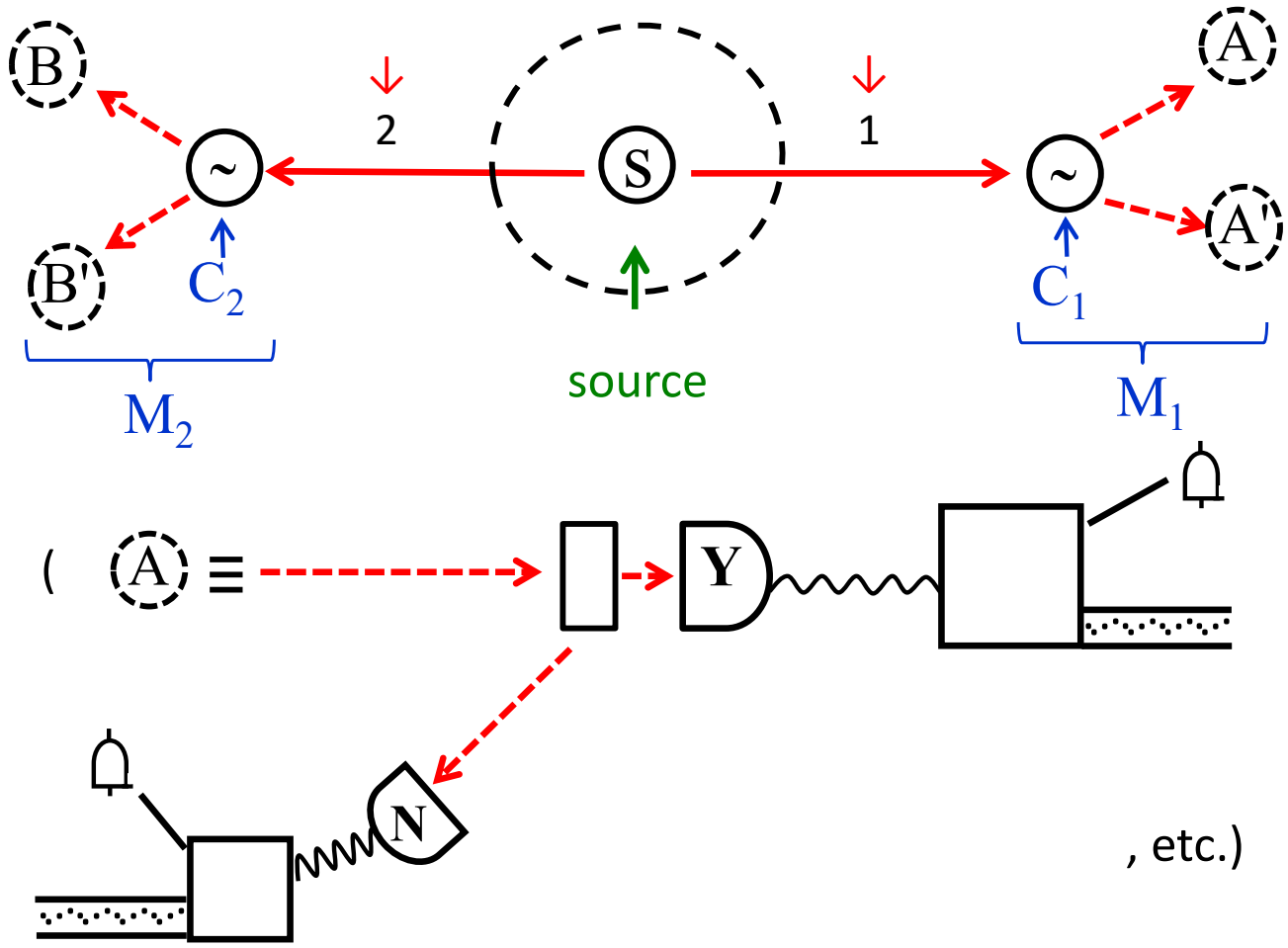
Workshop on “Correlated Quantum Matter”
in honor of Mohit Randeria and Nandini Trivedi

Kolkata,19 April 2024 (by Zoom)

2. THE EPR-BELL EXPERIMENTS (idealized)



Df: if object 1 is directed into measurement station A and
counter Y of A clicks, then A≡+1
counter N of A clicks, then A≡−1

CHSH inequality: all objective local theories (OLT's) satisfy the constraints

$$\langle AB\rangle_{exp} + \langle A'B\rangle_{exp} + \langle AB'\rangle_{exp} - \langle A'B'\rangle_{exp} \leq 2 \qquad (*)$$

(*) is violated (by predictions of QM, and) (prima facie) by experimental data.

Note: for purposes of refuting local realism, use of "source" is inessential! (correlations can be generated any way we please).

Objective local theories (OLT's) defined by conjunction of

(1) Realism ("objectivity") – physical systems have definite properties whether or not these are observed. (will replace by MCFD)

(2) Locality – no causal influence can propagate with velocity > c ← speed of light

(3) *Absence of retrocausality ("induction"): future cannot affect present/past
(will not question in this talk)

So: experimental refutation of CHSH inequality ⇒
either locality or realism (MCFD) false (or both)

*[Note: in SR (2) →(3), but we want to consider more general scenarios]

Recap: our tentative definition of "realism" was by proposition II.

Either it is a fact that counter Y would have clicked, or it is a fact that counter N would have clicked.

This is the statement of macroscopic counterfactual definiteness. So:

Do counterfactual statements have truth-values?

(common sense, legal system... assume so!)

A possible view on the meaning of counterfactuals*

"If kangaroos had no tails, they would topple over" seems to me to mean something like this: in any possible state of affairs in which kangaroos have no tails, and which resembles our actual state of affairs as much as kangaroos having no tails permits it to, the kangaroos topple over.

*David K. Lewis, Counterfactuals, Harvard U.P. 1975

Since "possible worlds" $\supset$ "actual worlds", let's consider: a specific theory I, in which photon pairs are specified by some state description λ such that $O \leq \lambda \leq 1$ and the (probability of) outcomes A, A', B, B' depend(s) on λ in some specified way, and a specific set of experimental runs, specified by the number of times $N_{k\ell}$ the combination of $k(= \boldsymbol{a}, \boldsymbol{a}')$ and $\ell(= b, b')$ was measured.

Df: total no. of runs $\equiv 4N$ (so $N_{k\ell} \sim N$)
No. of values of $\lambda \equiv$ M
"relative cardinality" $C \equiv {}^{N}/_{M}$

and ask

"Can we prove, entirely from assumptions about the way in which T makes predictions for the set of actually conducted experiments E, the CHSH inequality?"

1. Deterministic theory $T\,(A_i = A(\lambda_i), A'_i = A(\lambda_i), \text{etc.})$
   a) for unrealistic assumption $N_{k\ell}(i) = N$, yes, rigorously.

   b) otherwise, can show that probability of violating CHSH is $\sim exp - \alpha N_{k\ell} \to O$ for $N \to \infty$, irrespective of C.

2. Stochastic theory $T\,(p(A_i/\lambda_i)$ given)
   a) for C $\gg 1$ situation qualitatively same as in (1).
   b) for C $\gg 1$, generalization of proof apparently impossible.

Found Phys (2012) 42:80–85
DOI 10.1007/s10701-010-9508-1

Non-realism: Deep Thought or a Soft Option?

Nicolas Gisin

Received: 11 April 2010 / Accepted: 1 September 2010 / Published online: 11 September 2010

Abstract The claim that the observation of a violation of a Bell inequality leads to an alleged alternative between nonlocality and non-realism is annoying because of the vagueness of the second term.

Keywords Nonlocality · Bell inequality · Realism · Measurement problem

1 Introduction

In recent years the violation of Bell's inequality has often been interpreted as either a failure of locality or of realism (or of both). The problem with such a claim is that it is not clear what realism in this context should mean. In this note my goal is to look for a definition of realism compatible with the claim that it has been falsified.[1] Sometimes realism is defined as the hypothesis that every physical quantity always has a value.[2] But then, either this value is unaccessible, hence unphysical, or this value can be revealed by appropriate measurements (to arbitrary good approximation, at least in principle). Hence, these measurements have predetermined outcomes and realism is nothing but a fancy word for determinism. If so, first, why should one use the word local realism instead of local determinism? And second, Bell's inequality can be stated and proved without any assumption about determinism.

[1] My personal definition of realism—that clearly has not been falsified—is another issue. For me realism means [2], very briefly, that physical systems possess properties preexisting and independent of whether we measure the system or not; however these preexisting properties do not determine measurement outcomes, but only their propensities. Accordingly, there are realistic random events that reflect preexisting properties, as required by realism, simply the reflection is not deterministic.

[2] For example, in [1] A. Zeilinger at al. define realism as "the assumption that measurement outcomes are well defined prior to and independent of the measurements".

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Gisin's second claim:

To prove CHSH inequality, it is adequate to postulate the locality condition

$\forall$ a,b,λ

Prob. that both A and B stations register "Y"

$$p_{++}(\mathbf{a},\mathbf{b},\lambda) = p_{+}(\mathbf{a},\lambda)\, p_{+}(\mathbf{b},\lambda) \qquad \text{(etc. for } p_{+-}, \ldots) \qquad (*)$$

polarizer settings

Specification of 2-photon state (not necessarily by "hidden variable")

Once (*) is granted, algebra to obtain CHSH inequality is trivial.

However:

what does $p_{++}(\mathbf{a},\mathbf{b},\lambda)$ actually mean?

For any given pair of photons, **a,b** (by experimental construction) and λ (by assumption) take definite values. However, we need to postulate (*) also for values which are not taken, e.g. for $p_{++}(\mathbf{a}',\mathbf{b},\lambda)$! At least for continuous λ, cannot define this quantity in frequentist terms: it must refer to, not one, but a whole collection of experiments which we have not conduced:

"had we measured the results of a large ensemble of experiments with setting **a′,b** and state description λ, the distribution of (++) results would have been statistically consistent with the "value" $p_{++}(\mathbf{a}',\mathbf{b},\lambda)$" – i.e. not one, but a whole set of counterfactual statements.

$\Rightarrow$ "macroscopic counterfactual quasidefiniteness" (MCFQD)

The $64K question:

Is MCFQD any more acceptable than MCFD?