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PHILOSOPHICAL MOTIVATIONS OF BELL'S THEOREM AND THE EXPERIMENTER'S PROBLEM†

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For a physicist an important question that Bell's theorem leads us to ask is -- do natural phenomena or systems possess intrinsic properties independent of their observers. Or, more simply stated, do objective systems -- objects -- exist? We assume here that they do and examine the consequences and possible tests of this assumption. We expect that the objects present in a given spatial region must determine at least the probability for a given experimental result in that region. We also assume locality, i.e., that this probability does not depend upon experimenter's decisions (generated at random by an independent process) which are made totally outside of the backward light cone of our test object(s). Thus any correlations between the results of two different spacelike separated experiments must be due to the associated separated objects being correlated.

The above reasoning, contained in Ref. (1) leads us first to define an Objective Local Theory (OLT) as any theory for which the probability of a coincident response at the two space-like separated measurements in Bohm's Gedankenexperiment can be written as

$$p_{12}(a,b) = \int p_1(a,\lambda)\; p_2\,(b,\lambda)\; \rho\,(\lambda)\; d\lambda, \qquad (1)$$

Similarily for a response at, for example, detection 1 we have

$$p_1\,(a) = \int p_1\,(a,\lambda)\; \rho(\lambda)\; d\lambda \qquad (2)$$

(See Ref. (1) for a discussion of notation)

It should be noted that we are lead to (1) from various alternative naive motivations[2,3]. Hence, a direct test of these formulae is of profound importance to the conceptual foundations of modern physics.

In Ref. (1) it is then shown that these formulae directly imply the inequality

$$-1 \leq p_{12}(a,b) - p_{12}(a,b') + p_{12}(a',b) + p_{12}(a',b') - p_1(a') - p_2(b) \leq 0. \quad (3)$$

This is the general experimental prediction made by OLT's. Quantum mechanics, starting from different assumptions, makes a prediction for <u>some</u> realizations of this experiment which is at variance with (3). Thus experiments are needed to see which theory nature has chosen. So far, however, no direct experimental test of these predictions has been made. Such tests, although feasible, are in fact difficult. The reason is that in (3), singles count rates (p_1 and p_2) are compared with coincidence count rates (p_{12}). In present experiments the former are typically three orders of magnitude (frequently much more) larger than the latter.

None the less, two different classes of experiments have been performed. These, of course, need auxiliary assumptions to be useful. As a result, their value depends upon how reasonable the assumptions are. The first class consists of allowing particles produced in correlated pairs, each to independently scatter (incoherently) into an array of associated detectors. Examples are the positronium annihilation experiments and the proton - proton S-wave scattering experiments described at this conference. Unfortunately, a simple OLT counterexample (each particle having a predetermined scattering direction) suffices to show that rather strong additional assumptions are needed here. The primary difficulty with these experiments is the analyzers' inefficiency, and/or their attenuation.

The second class of experiments includes those for which the correlated particles are coherently scattered into a few well-defined beams by state selectors, with the selection super-position parameters under the control of the experimenter.

Examples of such experiments are the cascade-optical-photon polarization - correlation experiments suggested by Ref. 4. OLT counterexamples for these experiments are also possible[1], but they are much more difficult to produce. Correspondingly, the required additional assumptions are considerably weaker and more reasonable, and the experiments, more conclusive. This judgment is, of course, subjective, but it is reasonable. In these experiments, the primary difficulty is the low detector efficiency and poor angular correlation of the source.

Naturally, one desires an experiment for which inequality (3) is directly violated. Various conceivable methods for achieving this were suggested. For example, two-step photodissociation of Cl_2, followed by RF spin rotation, Stern-Gerlach state selectors, conversion of Cl to Cl^- by a surface reaction on a hot Tungsten surface, and finally electron multiplier detectors comprise such a scheme.

A final objection to existing experiments is that the separated parameter selections are not made with space-like separation. A method for doing this in the cascade photon scheme is discussed in these proceedings.

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